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The "Japanese" Beetle is Chinese.

By F. Muir.

For many years we have called our local pest by the name of "Japanese beetle," believing that it came to us from Japan. This came about through the first specimens that were sent away for identification being identified as *Adoretus tenuimaculatus,* a beetle only known from Japan. Recent investigations have shown that our local pest is not this species, but *Adoretus sinicus,* a beetle known from China, Annan, Formosa, Java, and Timor, as well as Hawaii.

The genus *Adoretus* contains from 150 to 200 species from all parts of the world which are all about the same size and mostly very similar in appearance. It is only by recent anatomical researches that the species have been satisfactorily distinguished and numerous wrong identifications, like our own, rectified. This shows the value of purely scientific research to economic work. For parasitic work it is necessary to know the native home of a pest, and a wrong identification might send a person off to a wrong quarter of the world to search for parasites.

The common species in Japan, *Adoretus tenuimaculatus,* flies and feeds by day and not by night, so I previously concluded that ours had changed its habits since its introduction in Hawaii. Now we know that it is a distinct species, with a distinct feeding habit.

And for our understanding of these things we have to thank the scientific investigator whose only ambition was to find anatomical differences in these insects.

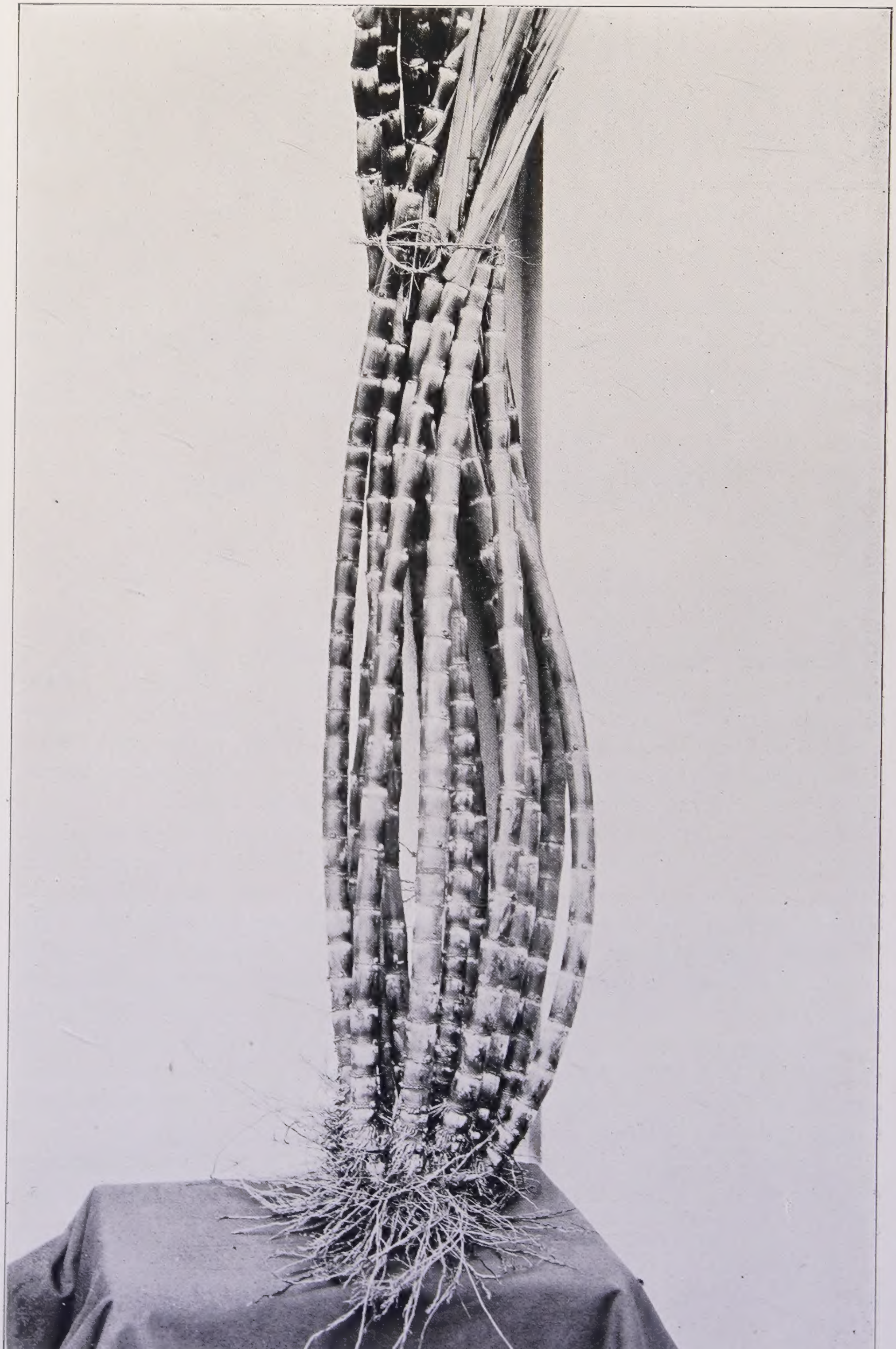


FIG. 1. A cane stool grown from a single seed of H 109.

The Cane Plant.*

By H. L. Lyon.

A cane plant begins its career as a single shoot or culm arising through the germination of a cane seed or the sprouting of a single eye on a cane cutting. As the primary shoot develops, secondary shoots arise through the shooting of the basal eyes on the primary shoot. Stalks of the third, fourth and succeeding categories may arise as part of the same plant through the shooting of the lower eyes on stalks of the preceding category; that is, secondary shoots arise from primary shoots, and tertiary shoots from secondary shoots, and so on.

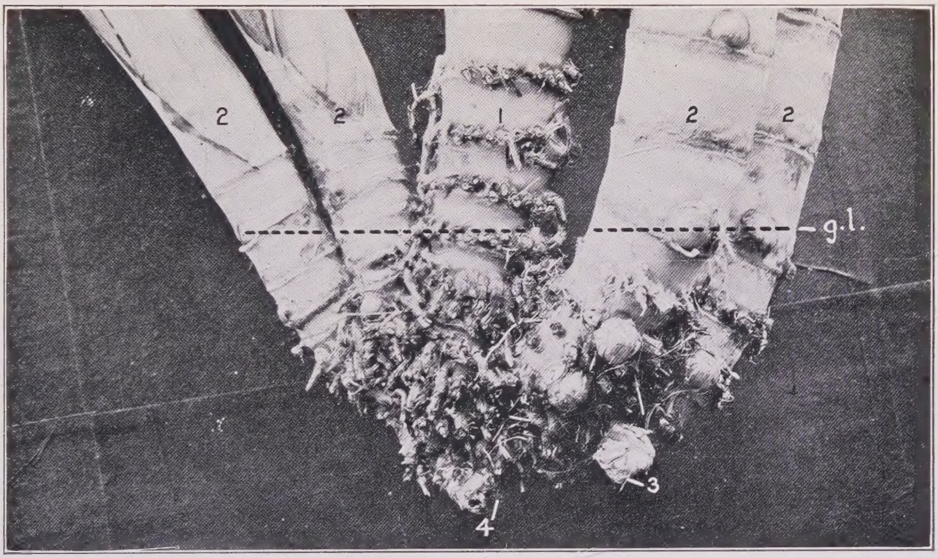


FIG. 2. Base of stool, showing origin of culms. 1—primary stick; 2—secondary sticks; 3—tertiary stick; 4—point of attachment to seed piece; g.l.—ground level.

On the plantations the term "stool" is commonly applied to any clump of shoots arising together in a compact group or cluster. Such a clump of shoots may include two or more plants, as it may have developed from two or more eyes on one or more cuttings. To be absolutely correct we should use the term "stool" to designate a single plant only.

A cane culm or stalk is differentiated into nodes and internodes. The leaves are attached to the nodes and a single bud or eye occurs on each node in the axil of the leaf. Roots may also spring from the node. The internodes are the smooth, cylindrical or barrel-shaped sections of the stem between the nodes. The internodes carry no appendages or outgrowths.

A cane stalk elongates through growth at its tip only. The inception or creation of new nodes and internodes takes place at the tip or growing-point of the

* A lecture delivered at the University of Hawaii in the "Short Course for Plantation Men."

stem; a new leaf and new bud being formed as appendages of each node. Each new leaf develops as a tightly-rolled tube which pushes its way up inside the tube formed by the preceding leaf; thus each stem carries at its summit a single upright roll or spindle of leaves from which the oldest leaf unrolls at intervals and falling away from the spindle begins its work as a mature leaf.

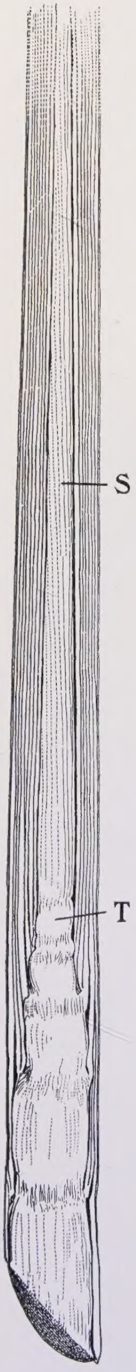


FIG. 3. Spindle of cane, with one side cut away.

A cane plant is anchored in the ground by branching roots which spring from the lowermost nodes of its culms, principally from those buried in the soil. (See Fig. 1.) Cane roots are cylindrical, pointed at their tips and more or less irregularly branched. In burrowing through the soil they meet with many hard obstacles and consequently bend and turn this way and that to get around the hard spots. They may also become very much flattened and distorted in order to enter narrow and tortuous channels in the soil. The younger healthy roots are more or less covered with fine soft hairs known as root-hairs.

While we speak of the nodes and internodes as the two general regions to be recognized on a cane stalk, still there are certain areas within each region which are clearly marked off and which have special functions.

The insertion of the leaf marks the basal end of each node, and we designate this the leaf-node. When a leaf drops off it leaves a narrow flange from the base of its sheath still attached to the leaf-node. This we call the leaf-scar. Just above the leaf-node is a band of tissue with a more or less undulating surface on which slight dome-like elevations mark the position of dormant roots. This is the root-band. Directly above the root-band is a ring of tissue which by enlarging on one side more than the other may cause the stem to bend. This is the stem-node.

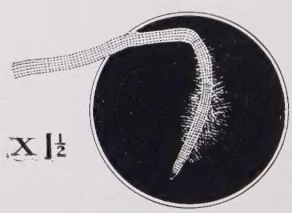


FIG. 4. Tip of root, showing root cap and root hairs.

On each node directly above the leaf-node and extending across the root-band is a single bud or eye. The eye is usually situated in a depression in the root-band, and this depression sometimes extends up into the internode above as the eye-groove. A band of white or grey wax usually extends around the upper end of each internode and is designated the wax-band. This wax is only superficial and may be scraped off without marring the internode.

Two general areas are to be recognized in a cane leaf, the free portion being called the blade, and that portion which closely invests the stem being called the sheath.

The blade is differentiated into a thick central strand, the midrib, and two lateral thin wings which are armed along their margins with sharp teeth. The wings of the leaf are filled with straight veins which run lengthwise of the leaf and quite parallel with each other. The course of these veins is not exactly lengthwise of the leaf, for they really diverge from the midrib, run out obliquely through the wing and

terminate at the margin of the leaf. When we look at the lower surface of the midrib we find that it is packed with veins, and if we follow up these veins we find that sooner or later they diverge from the midrib and pass out into the wing of the leaf. We can follow the veins of the leaf right down into the leaf-sheath, and, in fact, trace them back through its entire length to the stem.

The sheath is attached to the stem at the leaf-node, the line of attachment running a little more than just once around the stem, or in other words the edges of the sheath run by each other or overlap. The leaf-sheath is thickest in its central portion, thinning out toward the margins. The auricle is a very thin tab on the inner or covered edge of the leaf-sheath. It is a more or less useless appendage and may or may not be present on the leaf-sheath. In some varieties of cane, notably Lahaina, the sheath is covered on its outer surface with sharp hairs or bristles.

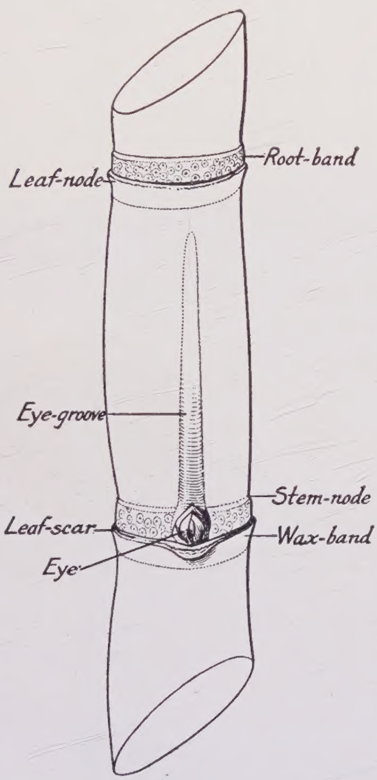


FIG. 5.

The ligule is a thin flap extending across the leaf at the upper end of the sheath. When the sheath is rolled up into a tube the ligule extends around the top of this tube on its inner side. There is usually present a row of hairs at the base of the ligule on its upper side.

The dewlaps are more or less bulging, hinge-like areas between the sheath and the wings of the blade. They usually differ somewhat in color and texture from the blade above and the sheath below. They are often covered with silky hairs on both their outer and inner surfaces when no hairs are present on the sheath below or the blade above. The dewlaps give elasticity to the leaf, permitting it to bend more freely at this point without breaking.

When a cane shoot or culm is about to tassel it ceases to produce leaves and in their place elaborates a flower-spike or inflorescence, a much-branched structure carrying a very large number of flowers. This tassel or arrow is pushed up through the center of the spindle and is eventually elevated well above the leaves, where it expands, opens its flowers and matures its seeds. When a culm flowers it converts its leaf-producing growing-point into a flower spike, and thereafter it can produce no more leaves or internodes and consequently cannot elongate further. Culms which have flowered can only show further growth through the shooting of their buds or eyes. Lalas are the lateral shoots produced through the shooting of the upper eyes on a cane culm. They are of frequent occurrence on culms that have flowered. Their internodes are usually short and hard.

Having noted all of the organs of the cane plant, let us examine the internal

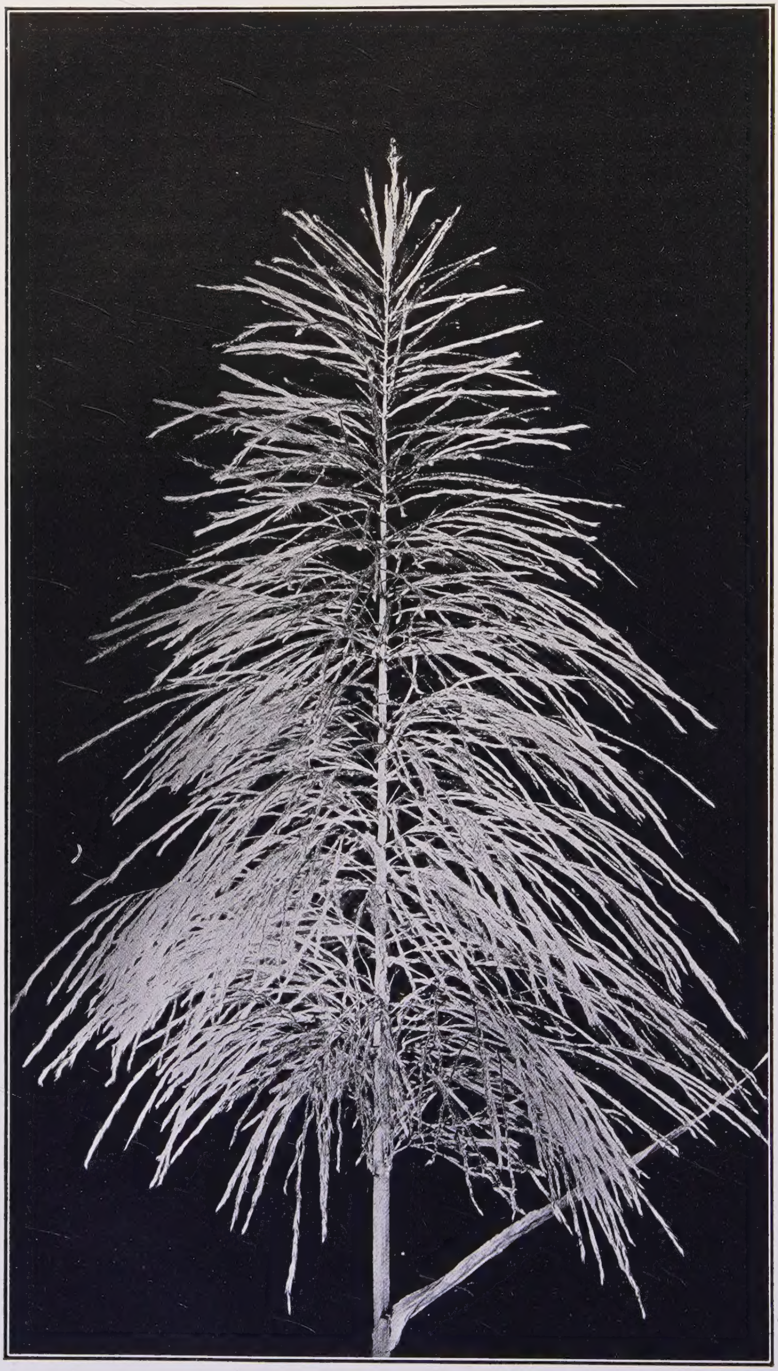


FIG. 6. Tassel of Yellow Caledonia cane.

structure of the more essential organs as far as we can distinguish these structures with the naked eye and a low-power magnifying glass. We will first make a cross-section or thin slice of the stem through an internode, and examine it by holding it up to the light. (See Fig. 8.) In this section we can readily distinguish several areas or kinds of tissue. The rind is the outer hard shell of the stalk. It has to supply strength to support the stem and protection to the softer tissues within. Then there are numerous darker or denser spots scattered all through a white, pithy tissue. These spots are the fibers of the cane in cross-section, and the white pithy tissue is the ground tissue or cortex. It is in the ground tissue that the reserve sugar of the plant is stored, and it is mostly from this tissue that we obtain the sweet juice when we crush the cane. Now let us take a piece of a stick consisting of two or three nodes and as many internodes

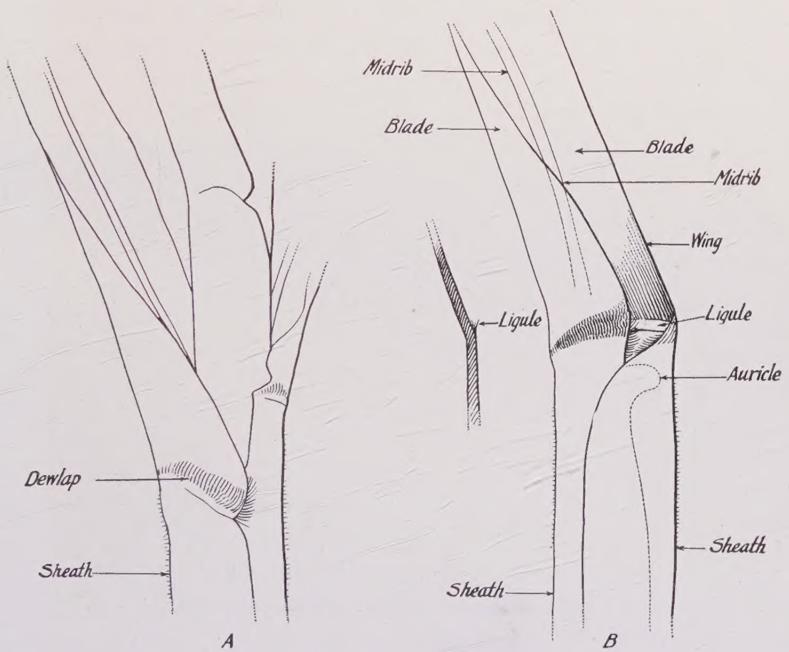


FIG. 7.

and splitting it lengthwise see how these same tissues appear in longitudinal section. In the first place the rind looks very much as it did in the cross-section, and no difference at all can be seen in the ground tissue. The fibers, however, are now seen lengthwise, and we find that they extend as straight strands through the ground tissue of the internode from node to node. In the node they branch, the branches bending one way or another to unite with branches of fibers which extend through the next internode, above or below, or pass outward into the leaf which stands on that particular node. If we examine a leaf-scar we can see the broken ends of the fibers which extended out into the leaf from the stem. If we examine the union of a leaf sheath and stem we can follow these fibers right up through the leaf-sheath and out into the blade of the leaf; they become, in fact, the veins of the leaf. If we were to follow the fibers downward through the

stem we should find that they continue through all the nodes and internodes and finally connect with fibers which run out into the roots.

The fibers constitute the water-conducting tissue of the plant. They enclose water pipes which are commonly termed vessels. In our cross-section we can actually see these vessels as tiny holes in the fibers. When we follow these fibers through the roots, stems and leaves of the plant we are following the course of the water pipes through the plant. This water pipe or water-vessel system is known as the vascular system, "vascular" simply meaning vessel. Supposing we were small enough to get into these water pipes in a cane root; we could then travel upward in these pipes into the stem, and by following the proper branches, go to any node or internode of the stem or out into any vein of any leaf.

The water pipes or vessels have rather thick walls of their own, but they are further strengthened by firm fibrous tissues around them, the resulting strand being called a bundle, and because it contains both fibrous and vascular tissue it is called a fibro-vascular bundle. The fibro-vascular bundles serve two main purposes in the building of the organs of the cane plant; they contain the water-conducting system and they supply strength to the members. In the stem the ground tissue is easily crushed or broken, but it is protected on the outside by the rind and reinforced within by the numerous strands or fibro-vascular bundles. The strength of the leaf is supplied almost entirely by its fibro-vascular bundles.

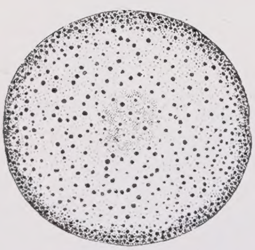


FIG. 8. Cross-section of a cane stalk, showing the distribution of the bundles or fibers.

LIVING SUBSTANCE OF THE CANE PLANT.

The actual seat of life in a cane plant is not in the hard parts of its members—stems, leaves and roots—but in a plastic, semi-fluid substance that lies in tiny chambers within these hard parts.

This living substance is known as protoplasm.

The living substance does not extend throughout the cane plant in one continuous, homogeneous mass, but is divided up into minute masses, each of which lies within a chamber. Because these units of protoplasm reside in individual chambers they are termed cells. The walls between cells are not absolutely solid, but are perforated by infinitesimally small holes through which slender strands of living substance connect the protoplasm of each cell with that of the adjoining cells. In fact, the protoplasm of the entire plant is connected up by living strands; in other words, it maintains telegraphic communication throughout the entire living body.

The walls of the cells are composed of non-living substance which is manufactured and molded into shape by the plastic living substance within.

If we could separate the protoplasm of a cane plant from the non-living substance of the plant without breaking down or otherwise injuring the cell walls, we should have, on the one hand, a shapeless mass of plastic material resembling in consistency the white of an egg; while on the other hand there would remain the stems, leaves and roots of the plant still perfect in form but without life. The hard part of the culms, leaves and roots but constitute the factory building which the living substance of the cane constructs in which to carry on the work whereby it is able to live and perpetuate itself.

The relation which the living substance bears to the non-living substance may be easily understood by considering the sequence of events in a hen's egg during incubation. The freshly-laid egg contains no hard parts whatsoever. It does contain a certain minute quantity of living substance situated on one side of the yolk, while the yolk and white of the egg are concentrated food materials placed there to feed the living substance when it begins to grow and build its own residence or factory, which we call the young chick.

Incubation causes the dormant living substance in the egg to start activities, and it begins to work over the available material, increasing its substance and supporting it by constructing cell walls. At first the cells are pretty much all alike in size and shape, each having only a very thin wall, but as the number of cells increases, some—because of their position and the work which they have to do in the completed factory or body—build thick, rigid walls of very hard material and become bone cells; others, as part of the intestines, build thin walls and assume a shape appropriate to their function. When the egg finally hatches the chick steps forth a highly complex mechanism supplied with bill, bones, nails, etc.—hard parts constructed by the living substance out of the plastic materials contained in the egg. There were no hard parts in the fresh egg, and no hard parts entered during incubation, yet the young chick is supplied with many structures of a firm nature.

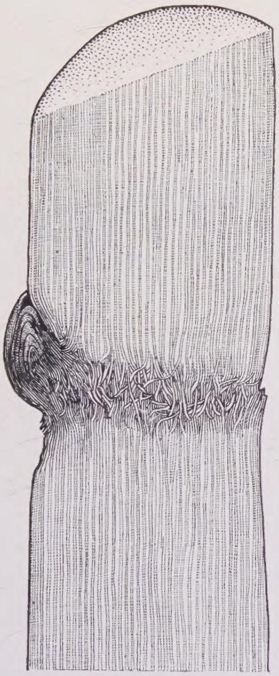


FIG. 9. Longitudinal section of a cane stalk, showing the bundles or fibers.

When we come to study the origin and development of the cane plant in the process of reproduction we shall find that each new cane plant comes into existence as a single cell but without even a cell wall. It begins its life as a naked mass of protoplasm. From the very first it receives only liquid food, and from this food it elaborates additional living substance, increasing its bulk and building cell walls of various shapes and thicknesses, depending upon the work which they must do in the plant body.

GROWTH OF PROTOPLASM.

Now, a cane plant, like every other living thing—plant or animal—sustains its life and adds to its own substance or grows by taking into its system non-living substance and converting it to its own uses, either adding to or repairing its own living substance or building structures (cell walls, etc.) to support and protect its substance.

Protoplasm is made up of a complex of chemical elements in combinations which we are unable to determine, for if we submit it to chemical analysis we kill it and it is no longer protoplasm. We can, however, determine what elements enter into its composition, and these we find to be carbon, oxygen, hydrogen, nitrogen, sulphur, phosphorus, calcium, magnesium, potassium and iron.

To grow, protoplasm must build new protoplasm out of non-living materials. Growth takes place through the building of new living substance out of non-living food materials. Additional protoplasm can come into existence only through the activities of existing protoplasm. Protoplasm is the only force that can create new protoplasm—"Only life begets life."

To build new protoplasm the existing protoplasm must have food containing all of the elements enumerated above. It requires them in very different quantities, however, for carbon, oxygen and hydrogen comprise most of its bulk.

All of the required elements occur in nature either singly or in simple compounds which are practically stable under natural conditions. In the living protoplasm they are put together in various complex combinations and compounds which are more or less unstable, and the protoplasm must do work, and hence expend energy, in order to force these elements together into these compounds.

Growth of the protoplasm is simply a matter of building complex chemical compounds and complexes of these compounds out of the elements or simple compounds. This work is chemical work, and the protoplasm must find the energy to do this work. Where does it get this energy? By simply causing one complex compound to go to pieces and in so doing to give up its energy, which is then used in the building of others. We do much the same thing in a simple way when we burn bagasse, which is a complex of compounds built up by the protoplasm of the cane plant. We cause the compounds in the bagasse to disorganize rapidly into simpler compounds. This releases the energy which was expended in building up these compounds, and we then employ this energy to make steam which operates the machinery in our mills. We release the energy stored up in the bagasse and convert it into mechanical energy which we direct to our own purposes.

When we explode gasoline in the cylinder of an engine, or powder in the barrel of a gun, we release chemical energy stored up in complex compounds, and convert it into mechanical energy. Protoplasm does much the same thing. It causes complex compounds to go to pieces and then employs the energy released; in fact, it may do exactly the same thing, but under better control. It oxidizes compounds and thus obtains energy, but it does it more economically than we do when we burn bagasse, for we always lose a lot of the energy released.

The growth of protoplasm is essentially chemical work, requiring chemical energy to perform, so the protoplasm converts the energy, released by causing one set of compounds to disorganize into chemical energy, and employs it to build up the new chemical compounds and complexes of compounds which constitute living substance or protoplasm.

To grow, therefore, protoplasm must have the elements or compounds required to build up its own substance, and, at the same time, it must have complex compounds to yield energy to do the work. To supply these needs, it must have food which furnishes all these requirements; the material to build with, and the energy to do the building.

The protoplasm of an animal must have complex compounds to begin with. The animal must therefore secure as food the highly organized compounds created by the protoplasm of some other animal or plant. Its only source of energy is in compounds already constructed. The protoplasm of a plant, however, has another

method of turning available energy to its own use. It constructs a green substance which we call chlorophyll. This chlorophyll, when exposed to sunlight, can convert the radiant energy coming from the sun into chemical energy. Chemical energy is thus made available to the protoplasm of the plant and it uses it to construct a complex compound, starch, which constitutes its chief energy-producing food. Starch consists of carbon, hydrogen and oxygen. These elements occur abundantly in nature as water and carbon dioxide. Water is a compound of oxygen and hydrogen, while the air is composed in part of the gas carbon dioxide, which is readily soluble in water. Now, to secure its work-yielding food, the protoplasm employs the energy which it obtains from the sun through its chlorophyll to build up starch out of carbon dioxide and water.

The leaves of a plant are the organs built for the very purpose of making starch out of carbon dioxide and water. In these structures the protoplasm concentrates chlorophyll, and, bringing water and carbon dioxide together in its presence, manufactures starch. Having secured the starch, it proceeds to use it just as the protoplasm of an animal does the complex compounds which it seizes as food but does not itself create.

Protoplasm cannot build new compounds directly out of insoluble compounds. It must have its materials in soluble form before it can work them over under absolute control. The protoplasm of a plant must even get the gas carbon dioxide into solution in water before it can use it in the manufacture of starch.

Now, starch is an insoluble compound, and so are many of the compounds which animal protoplasm seizes as food. In order to get these insoluble compounds into solution so it can use them, protoplasm makes use of certain peculiar substances which we call digestive fluids, ferments or enzymes. These enzymes are non-living chemical tools constructed and operated by the protoplasm. They are of many sorts, for each enzyme can digest only one type of compound. The protoplasm of our own bodies must produce an enzyme to digest milk, another to digest meat, another to digest starch, etc.

Now, when the protoplasm of the cane plant constructs starch it must still digest this starch into a soluble compound before it can use it; in fact, it is in exactly the same position as the protoplasm of an animal that has stolen starch from some plant for its own use. To digest its starch the protoplasm of the cane plant makes use of the enzyme which we call diastase. This enzyme causes starch to change over into a soluble compound, cane-sugar or sucrose, which is the main source of energy as well as of carbonaceous food for the cane plant.

Growth of the protoplasm results from a series of chemical processes controlled by the protoplasm itself. These processes entail the building up and breaking down and building up of compounds in endless sequence. All of these controlled chemical processes are spoken of collectively as metabolism.

In its metabolism the protoplasm of a plant constructs more compounds than it destroys. In its metabolism the protoplasm of an animal destroys more compounds than it constructs.

The plant gets its chemical energy from the sun; the animal gets its chemical energy from compounds manufactured by other organisms.

To live and grow, the protoplasm of the cane plant must have light, air, water and soluble compounds containing nitrogen, sulphur, phosphorus, potassium, calcium, magnesium and iron.

From the light it obtains its energy or power; from the air it secures its carbon in the shape of carbon dioxide; and from the soil it obtains all the rest of its food materials in solution in water.

The body of the cane plant—stem, leaves and roots—constitutes the factory, built by the protoplasm for the purpose of carrying on its life work, which is chiefly a matter of getting food. Its one great problem is to live, and in order to live it must obtain food. The body which it constructs and operates represents its method of working out this problem.

Having selected the conditions of soil, moisture and temperature under which it prefers to grow, it has molded its body structures or organs to do the necessary work under these conditions.

It must burrow in the soil after water and soluble compounds, and so builds roots which are specialized organs to do this particular kind of work. It must expose chlorophyll to the light, and builds leaves specialized to do this work. Then it must have a supporting structure to carry these leaves and hold them up into the light, and it has elaborated the stem or stick for this purpose.

Now, the protoplasm working in the roots must receive carbonaceous food made in the leaves, for it is working in the dark and cannot make starch for itself. The protoplasm in the leaves must receive water and soluble compounds absorbed from the soil by the roots, while the stem must receive materials from both roots and leaves.

In constructing its factory, therefore, the protoplasm must provide means for transporting material from each organ to all other organs of its body. So in addition to its manufacturing operations it has to provide transportation for both crude and manufactured materials.

Let us now see how the protoplasm of the cane plant works out these problems. First of all, we must make a more careful study of the protoplasm itself. Taken by itself, protoplasm is a slimy, viscid, mucilagenous substance, much resembling in color and consistency the white of an egg. Alone, it has no rigidity, and so has to supply rigidity by building a meshwork of firm walls through its substance. In so doing it distributes itself in small chambers or cells, the portion in each cell being a more or less independently operating unit. The protoplasm in all the cells is connected by fine strands and works together for the common good, but the work done by each cell must depend upon its position in the plant body: the cells in a root cannot do the same kind of work as the cells in a leaf, and vice versa.

To study the workings of the protoplasm of the cane plant we must therefore first examine the structure and workings of a cell.

The protoplasm in a cell is differentiated into two essential areas, the nucleus and the cytoplasm. (Fig. 10.) The nucleus is a highly complex structure separated off from the cytoplasm by a thin membrane. The nucleus is the controlling and directing center of the cell, while the cytoplasm is the portion in which the chemical operations are performed. A cell may be likened to a chemical laboratory in which the nucleus is the chemist and the cytoplasm the chemicals and apparatus.

If a portion of the cytoplasm is destroyed the nucleus may, by operating the remaining cytoplasm, construct new cytoplasm and repair the damage; but if the nucleus is destroyed, the cytoplasm is helpless to do anything but disintegrate, go to pieces, die.

In addition to the nucleus and cytoplasm, which are alive, there is always present in the cell a considerable amount of water containing soluble compounds; this is known as the cell-sap. Protoplasm, when active, always keeps itself bathed in water; as a matter of fact, it cannot operate unless it does have a large amount of water at its immediate disposal, and the protoplasm in each cell keeps a supply on hand as the cell-sap. In this cell-sap it holds soluble materials which it may use as food or which it has manufactured and wishes to store up or pass on to other cells.

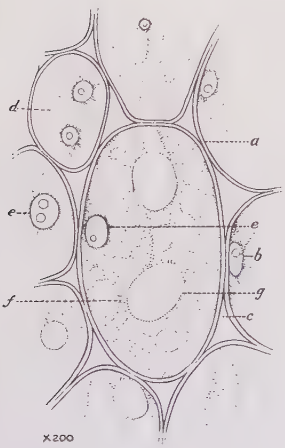


FIG. 10. A plant cell. a—cell wall; b and e—nuclei; c—intercellular air space; d—cell with two nuclei; i. e., caught in division; f—protoplasmic network; g—vacuole containing cell sap.

Besides operating with chemicals in its cytoplasm, the nucleus also constructs and manipulates conspicuous apparatus which is useful in its work. This apparatus takes the form of small, more or less rigid bodies which we call plastids. The protoplasm of plants uses plastids for several purposes, but that of the cane makes extensive use of them in one operation only, and that is in the manufacture of starch. The green coloring matter or chlorophyll is held within plastids which are called chloroplastids or simply chloroplasts. (Consult Fig. 16.) The chloroplasts of the cane plant manufacture starch which is converted into sugar and used as food by the protoplasm of the cell in which it is produced or sent on to the protoplasm of other cells for immediate consumption or for storage for future use.

The cane plant stores its surplus food as sugar, but many other plants store it as starch. Starch is an insoluble material and consequently is not as easily lost as sugar.

The protoplasm of the Irish potato manufactures starch in the cells of its leaves in exactly the same manner as does the protoplasm of the cane plant; and in exactly the same manner it converts this starch into sugar and transports it to other parts of its body. The surplus sugar is not stored as sugar, however, but is converted back into starch again in underground stems or tubers by other plastids which work in the dark. These plastids are called leuco-plastids, and the protoplasm gets energy to operate these plastids by releasing some of the energy locked up in the complex compound, sugar.

Fortunately for us, the protoplasm of the cane plant does not employ leucoplastids, but stores its excess food in the form of sugar.

The cell walls which give rigidity to the plant body and protection to the protoplasm, are composed of a substance, cellulose, which has exactly the same composition as starch. It is, of course, derived from starch, being built up out of the materials supplied to the protoplasm through the conversion of starch into sugar by the enzyme diastase. Like starch, cellulose is composed of carbon, hydrogen and oxygen; and, furthermore, these elements occur in exactly the same proportions in both compounds. However, the elements are put together in a different manner, for there are many and decided differences between starch and cellulose. The latter is more compact and a far more permanent compound than the former. Our own protoplasm can digest and use starch as a food, but it cannot digest and use cellulose to any extent whatever.

We are familiar with starch as corn starch, potato starch, etc. Cotton fiber and, consequently, cotton cloth, are almost pure cellulose.

The cell walls around the living cells in the cane plant, so long as they remain of pure cellulose, are saturated with water, and water or cell-sap may soak through the walls between the adjacent cells, so soluble materials like sugars may readily pass through the walls; in fact, this is the very way in which sugars and other soluble compounds are passed about in the plant; they simply go through the cell walls much as cane juice goes through a piece of filter paper.

Their passage through the cell walls is not a mere physical matter, however, like the passage of the cane juice through the filter paper, for the movement of soluble materials in and out of a cell is controlled to a large extent by the protoplasm in that cell.

The protoplasm of a cell always disposes itself as a layer completely covering the inside of its cell or chamber. At every point a layer of protoplasm lies between the cell sap and the cell wall. The passage of cell sap in and out of the cell is regulated by the protoplasm which may accelerate or prevent its passage.

At many points in the plant body there are cell walls through which the protoplasm does not wish water to pass under any circumstance. The walls forming the very outside covering of the stem and leaves are of this nature, and the protoplasm makes them practically impervious to water by impregnating their cellulose with a substance, cutin. Then, at other points, it wishes to create stronger walls than those of pure cellulose, and it does this by impregnating their cellulose with a substance, lignin. Cell walls which have been impregnated with lignin we say are lignified. Wood is lignified cellulose.

GROWTH OF THE CANE PLANT.

We have found that the protoplasm of the cane plant is organized as an aggregation of cells, each cell being a working unit in the organization. There is, to be sure, a co-ordination of all the cells, all working together for the common good. But the cells in different organs must do different kinds of work and are necessarily different in some respects. Cells doing a common kind of work are usually quite similar, and work together in a harmonious group. Such a group of cells is spoken of as a tissue.

As the protoplasm grows and produces new organs and new tissues it must create these new organs and new tissues by organizing new cells. For each new cell it must have a nucleus and cytoplasm. We have already found that new protoplasm only comes into existence through the activities of existing protoplasm, so it follows that new cells are created only by existing cells, and new nuclei by existing nuclei.

In normal growth of the cane plant new cells are formed through the division of existing cells and new nuclei through the division of existing nuclei. The nucleus is itself a very complex structure. When a cell is about to divide, the nucleus first divides its materials into two exactly equal parts. Each part then organizes itself as an independent nucleus. The two daughter nuclei thus formed move away from each other and proceed to build a cell wall between themselves, dividing the old cell into two chambers. Each nucleus retains about half of the cytoplasm in its own cell.

Many of the cells in the cane plant early lose the power to divide. We know that the older joints of the stem do not elongate, and the leaves do not increase in size after they have unrolled from the spindle. When these structures cease growing their cells have ceased to divide. Their protoplasm may be working, and, in fact, does work until it becomes exhausted and dies; but it does not increase its own bulk and produce new cells by division. Such cells which have ceased to divide and have settled down to one kind of work are known as permanent cells, and the tissues which they comprise are known as permanent tissues.

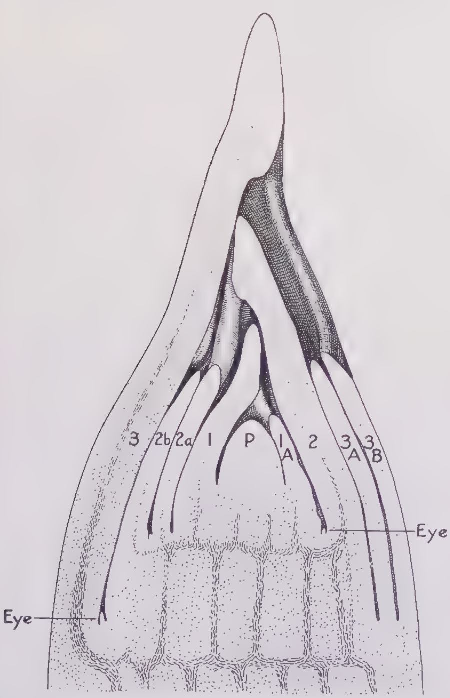


FIG. 11. Vertical section of the tip of a cane stalk. 1, 2 and 3—the three youngest leaves. P—growing point.

The growth of the protoplasm and the production of new cells and new tissues takes place, for the most part, at the tips of the stems and roots. Here we find masses of thin-walled cells more or less alike, which are growing and constantly dividing. These cells are called embryonic cells, since they are capable of further growth and division, and a group of these cells is spoken of as embryonic tissue. Since these embryonic tissues are located at the tips of the stems and roots, they are usually alluded to simply as the growing points.

The embryonic tissue comprising the growing point of the stem is hemispherical or dome-shaped. (Fig. 11.) It increases in size through the rapid growth of the protoplasm within and the constant division of its cells. As it enlarges the outer edge grows more rapidly than the center, and this causes the formation of a ridge around a small central dome. This ridge is not a complete circle, but has two

ends which overlap or run past each other. Now this ridge rises very rapidly as a plate of tissue which is rolled up with its edges overlapping, forming a veritable tube. As soon as one ridge has been formed on the growing point and begins to push up as a tube, the dome again enlarges and another ridge is formed, which in turn pushes up as a tube just inside of the tube developed from the previous ridge. At the growing point of the stem this process goes on, ridge after ridge being formed and each one developing into a tube which pushes up inside of the previously-formed tube. These ridges are the embryonic leaves. They are formed one after the other at the growing point of the stem, the youngest leaf being always on the very inside of the roll and protected by all the leaves previously formed which remain rolled up in the spindle. At first the leaf is composed of embryonic tissue only; all of its cells grow and divide. But as it elongates the cells begin to take on special shapes according to their position in the leaf, and by the time the leaf is exposed to the air and light through the unrolling of the leaves outside of it, its cells have become permanent cells, organized into permanent tissues.

Now, while the growing point of the stem is elaborating new cells and producing the ridges on its upper surface, which develop into leaves, it is also forming new cells which are added to the tissues of the stem. In fact, the growing point forms new cells throughout its entire extent, some being molded into leaves, while others are organized into nodes and internodes which are added to the stem. For every leaf rudiment that is formed the growing point lays down tissue which is later transformed into the corresponding node and internode of the stem. As the rudiments of the leaves grow and assume their permanent shape in the spindle, the nodes to which they are attached also grow and assume their permanent form. All of the tissue in the leaf eventually becomes permanent tissue, incapable of further growth. Most of the tissue of the stem soon becomes permanent tissue also, but a small amount is always held as embryonic tissue. When each node is formed a small amount of its tissue is retained as embryonic tissue and transformed into a miniature growing point. This growing point produces a few scale-leaves to protect itself and then becomes dormant; that is, it stops growing—goes to sleep, and remains asleep until conditions arise which cause it to grow again. These dormant growing points are the buds or eyes, and we know that they must contain dormant growing points of stems, for when we plant cuttings these eyes shoot and produce new stems.

In addition to the growing points in the eyes there are small masses of tissue in each root-band which remain embryonic. These masses are located directly beneath the rind and their position is marked by little mounds or pimples on the surface of the root-band. Under favorable conditions these masses of embryonic tissue will begin to grow, and pushing through the rind become the growing points of roots. And right here let us examine the growing point of a root. A healthy cane root is more or less pointed, and in growing it drives this point into the soil. Now, this is pretty rough work, and no delicate embryonic tissue could stand it. The root has no appendages like leaves to protect its growing point, and so it has to gain protection by producing a special protecting organ, the root-cap, which it pushes ahead of the growing point. To understand the exact posi-

tion of the embryonic tissue in the point of a cane root we only have to refer to the accompanying drawing (Fig. 12), which represents a longitudinal section through the very center of the root tip. The embryonic tissue is located at the point marked (m). This tissue grows, adding new cells to the root-cap (rc) ahead of it and building new tissues onto the body of the root behind it. As the root pushes into the ground the surface of the root-cap may be worn and injured

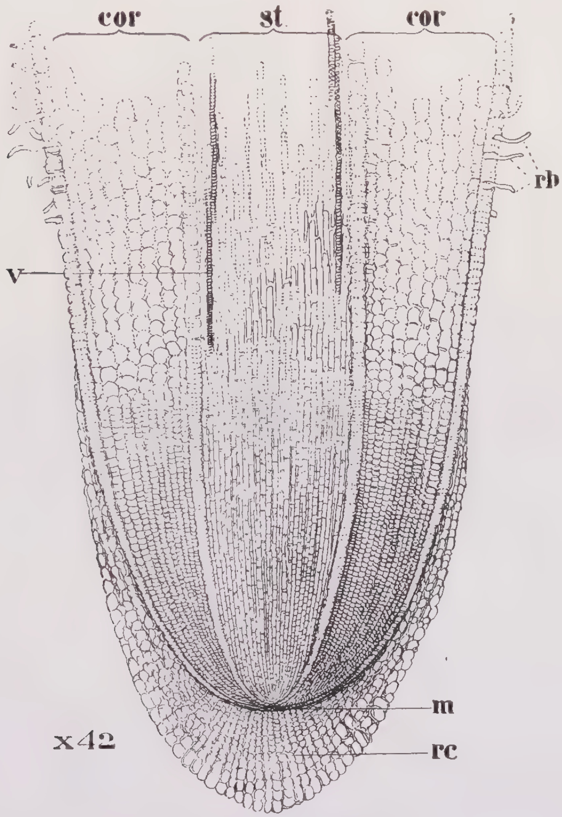


FIG. 12. Longitudinal section of the root tip. cor—cortex; st—central cylinder; rh—root hairs; v—vascular tissue; m—growing point; rc—root cap.

through contact with hard objects in the soil, but as the surface wears off, the cap does not become thinner, for it is constantly being added to on the inside through the activities of the cells at the growing point.

The tissues of the root become transformed into permanent tissues only a short distance back of the growing point—that is, most of the tissues do—but there are always a few layers of cells extending clear around the root and some distance beneath the surface that remain embryonic or capable of further growth. At various intervals there will be organized in this embryonic tissue new growing points of roots. These will start to grow, force their way right through the tissues lying outside of the embryonic area, and push their way into the soil as lateral roots.

The growing point of the stem is at the surface, and new leaves and new stems always arise as outgrowths from the surface, but the growing point of the root is always covered, and new roots always spring from tissues lying beneath the surface. This is as true of the roots that arise in the stem as it is of the roots that arise within other roots. Examine young roots springing from the root-band on a cane stem. Are they outgrowths of the surface or do they push out from beneath the surface? The embryonic tissues at the growing points of the stems and roots of the cane plant are not food-making tissues; in fact, they must do their work in the dark and consequently cannot manufacture starch. Their function is to grow and add to the permanent tissues, and their protoplasm is fed on liquid food which is manufactured by protoplasm in the permanent tissues and then handed on from cell to cell until it reaches the protoplasm in the growing points, where it is elaborated into new protoplasm, which is in turn organized into new cells and new tissues.

PERMANENT TISSUES OF THE CANE PLANT.

Now we are ready to study the permanent tissues of the cane plant, and to do this profitably we must bear in mind how they come into existence and at the same time consider the functions of the various tissues; that is, the nature of the work which each tissue performs. To understand the structure of the factory which the protoplasm of the cane plant builds we must visit the factory in the process of construction and in operation.

The cane plant has three great tissue systems: (1) the tegumentary-tissue system, which is the outside covering of all members. It is the integument or epidermis which forms a continuous covering of all organs—stems, leaves and roots. (2) The vascular-tissue system, which includes the fibro-vascular bundles extending throughout all members, and (3) the ground-tissue system, which begins just within the tegumentary tissue and surrounds and encloses the vascular-tissue system.

These three tissue systems are added to by all actively-growing points; they are added to at the tip of each culm and at the point of each growing root.

At the growing point the cells are all alike, but as cells are pushed off from the growing point into leaves, stems or roots they soon begin to modify their shape and to construct cell walls according to the work which they must do in the members to which they have been assigned. They leave the growing point as raw recruits but are soon marshalled into companies and battalions and equipped according to the duties which they must perform in the campaign. These companies, battalions and regiments are the tissues, their members are living cells which were exactly alike when they marched away from the growing point.

Let us examine a root first. The three tissue systems become evident a very short distance away from the growing point. The outermost layer of cells forms the tegumentary tissue or epidermis, and some of its cells soon grow out into long slender tubes, the root-hairs. The vascular tissue-system of the root consists of but one large vascular bundle which is often called the central cylinder

or stele. (Fig. 13.) The cells in this central cylinder change their shape very quickly. This change is most marked in the direction of the axis of the root; that is, the cells very soon assume the shape of long tubes. The cells, which are in direct line with the existing vessels, quickly build thick lateral walls and then break down their end walls and thus add their length to the vessels or water pipes. In this way the vessels are built onto at their ends, the construction of vessels or the extension of the water pipes closely following the growing point. There are two types of vessels constructed in the stele; small vessels which are quickly constructed and hence extend pretty well up to the growing point, and larger vessels

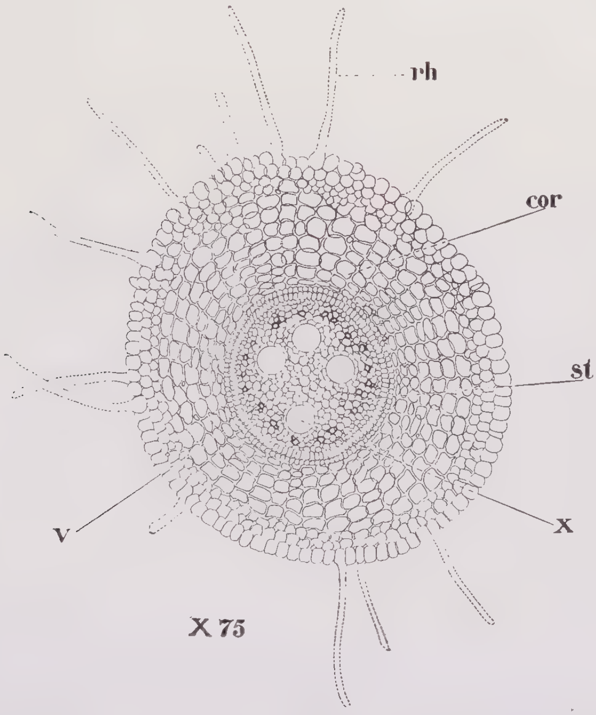


FIG. 13. Cross-section of the root tip. cor—cortex; st—central cylinder; rh—root hairs; v and x—vascular tissues.

which are built somewhat more slowly and hence do not extend as near the growing point as do the smaller ones. To understand the origin, nature and position of these structures compare figures 12 and 13. When a cell is added to a vessel the protoplasm of that cell dies and disappears. The bit of living substance has done its work and it is promptly sacrificed for the good of the plant.

The cells which enter into the ground tissue system enlarge very much but do not change their proportions to any great extent; their protoplasm remains alive and usually includes a large amount of water or cell-sap within its cell wall.

Now, how does a root work? It burrows in the soil after water containing the substances in solution which the plant must obtain from the soil. The protoplasm in the thin-walled root-hairs is particularly well situated to pull in this

water through its cell walls. It then hands it on to the cells in the cortex or ground tissue, which in turn pass it on to the cells in the stele. The protoplasm in these cells then forces it into the vessels. Now, these vessels communicate with all parts of the plant, and the protoplasm at all points above in the stem and leaves may pump water out of the vascular tissue system. The roots must absorb enough water and pump it into these vessels to supply the needs of all the protoplasm throughout the plant.

The growing point of the stem gives rise to the three tissue systems in much the same way as does the growing point of the root, but the resulting permanent tissues are much more complicated. The tegumentary tissue system is developed from the surface layer of cells of the growing point. It extends in one continuous layer over all the leaves, nodes and internodes. The vascular tissue in the stem is not differentiated as a single central cylinder as in the root, but as many cylinders or bundles. We have already noted the position of these bundles in the mature stems and leaves. Now, when the nodes and internodes are being differentiated out of the embryonic tissue derived from the growing point, those cells which happen to be in the course where the vascular bundles should run are constructed into vascular bundles. A short distance back of the growing point the cells which are to become a part of a vascular bundle begin to elongate, and a little further away from the point those cells which are to become vessels can be distinguished because they are forming the thick walls characteristic of vessels, while still farther back the completed vessels may be found in working order. If we pick up a completed fibro-vascular bundle in the stem and follow it up towards the growing point, we will first come to a point where vessels are just being put into commission, then above these we will find vessels in the course of construction; a little further up no vessels can be distinguished, but a bundle is still marked off because its cells are longer than the surrounding cells of the ground tissue; then as we approach the growing point this difference is no longer apparent, the cells being all alike.

The protoplasm of the cane plant extends the vascular system by building new tissues onto the ends of the existing bundles. It takes for material the cells that lie in the path where these vascular bundles should run.

The same thing happens in the building of the leaf. The young leaf is all embryonic tissue. The protoplasm extends the vascular tissue into the leaf by simply making vascular tissue out of those cells which lie in the course where vascular tissue should run.

All the tissue lying inside of the tegumentary tissue system or epidermis of the stem and leaves and not used in making vascular tissue becomes ground tissue. Just as the tegumentary tissue of the leaf is continuous with that of the stem, and the vascular tissue of the leaf is continuous with the vascular tissue of the stem, so also is the ground tissue of the leaf continuous with the ground tissue of the stem. Most of the cells in the ground tissue build only very thin walls and they are prone to pull their walls away from the walls of their sister cells, thus leaving small spaces which may be filled with air. These spaces are known as intercellular spaces. (Consult Figs. 10, 15 and 16.) These intercellular spaces communicate throughout the ground tissues and permit the circulation of air through these tissues. In this way air, which is of course part oxygen, is made readily avail-

able to the protoplasm, and it takes it in and uses it to oxidize complex compounds and release their energy. To understand the origin and relation of the tissue systems of the leaf and stem, make a careful study of the diagram, Fig. 11.

Now that we know how the tissues come into existence, let us examine more critically the permanent tissues, keeping in mind the work which they do in the body of the cane plant. We can best begin with the fibro-vascular bundle.

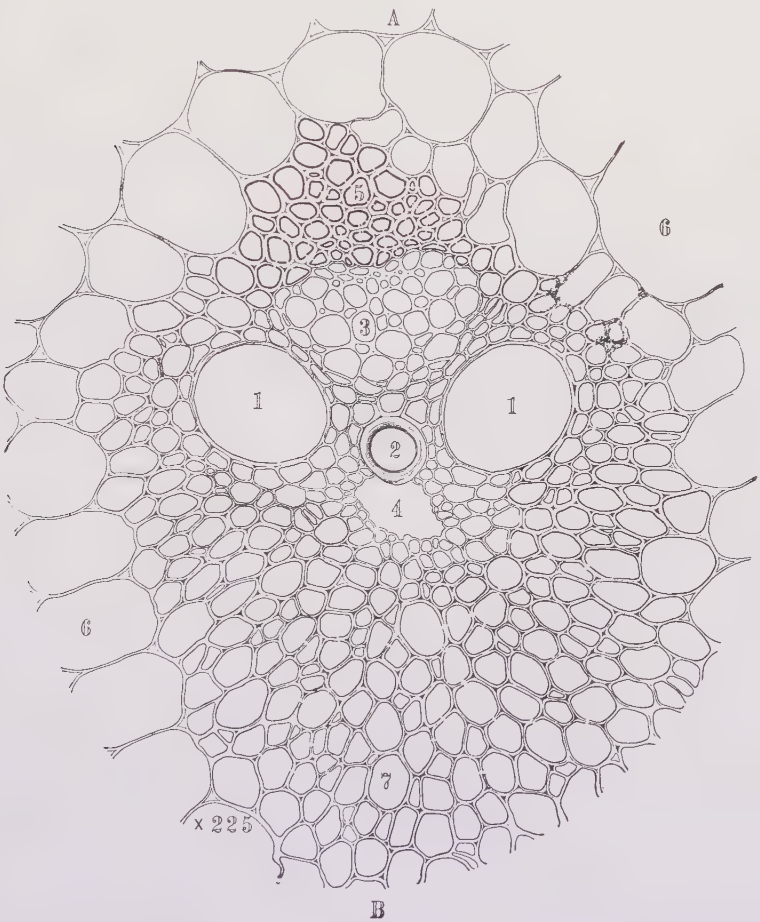


FIG. 14. Cross-section of a fibro-vascular bundle of the stem. 1—two large vessels; 2—an annular vessel; 3—a sieve tube; 4—air space; 5 and 7—thick-walled cells of the fibrous tissue; 6—thin-walled cells of the ground tissue.

Fig. 14 shows the arrangement of cells in a fibro-vascular bundle of the stem as seen in a cross-section of the bundle, and Fig. 15 represents a longitudinal section through the same bundle from A to 4. There are two large vessels marked 1, and one small vessel marked 2 in Fig. 14. 2 is a primary vessel, such as we noted in our discussion of the formation of vessels in the stele of the root. It is finished and working before the protoplasm can get the larger vessels 1 and 1 in commission.

The walls of the vessels are always very much thickened and reinforced with a lining which, in the primary vessels, always takes the form of rings or spiral bands (Fig. 15, V), while in the larger, secondary vessels this lining is always a meshwork much resembling in structure some of the patent screens now in use in sugar centrifugals. The walls of the vessels are also impregnated with lignin, which gives them greater strength than though they remained pure cellulose.

The tissue at 3 in Fig. 14 is the so-called sieve-tissue, which we have not previously mentioned. It is a type of conductive tissue the elements of which are called sieve-tubes. These sieve-tubes are very long, slender cells which stand end to end, very much as the cells do which become vessels. (See Fig. 15.) The cross-walls between sieve-tubes, however, do not entirely break down, but they become perforated with many small holes, and thus form a sieve or sieve-plate. Accompanying each sieve-tube is a long, slender cell which is just as long as its sieve-tube. This cell is called the companion-cell. It always contains a nucleus and cytoplasm, and it would appear that the companion-cell engineers the operation of its sieve-tube, for the sieve-tube, like a vessel, loses its protoplasm as soon as it is completed, and it is operated by the rest of the protoplasm of the plant as part of its transportation system. The protoplasm moves a rather viscid mass of material through the sieve-tube tissue. This material has the consistency of thick molasses. It may contain considerable sugar, but it also contains gums and other more or less insoluble compounds manufactured by the protoplasm but moved with difficulty through solid walls by diffusion, in the way that the readily soluble sugar is moved.

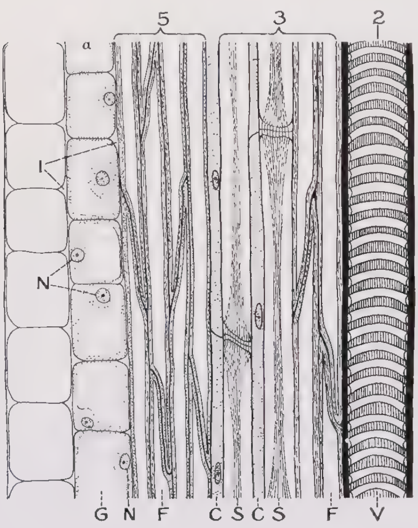


FIG. 15. Longitudinal section of a vascular bundle of the stem; 2 and V—annular vessel; 3 and S—sieve tube tissue; 5 and F—fibrous tissue of thick-walled cells; C—companion cells; N—nuclei; G—ground tissue; I—intercellular spaces.

Now, referring again to Fig. 14, all the tissues of the fibro-vascular bundle, other than the vessels and the sieve-tissue—that is, the tissue at 1, 2 and 3—is fibrous tissue, made up of long, pointed cells, with very thick walls and narrow cavities. These cells are marked F in Fig. 15. Their function is to give strength to the bundle. This fibrous tissue is called sclerenchyma. In Fig. 14 the cells of the ground tissue which directly surround the fibro-vascular bundle, are marked 6, and in Fig. 15 they are marked G. Note their relatively thin walls and the numerous inter-cellular spaces between them.

Now we come to a consideration of the structure of the leaf, which is by far the most complicated organ of the cane plant. It is the most complicated because its tissues are the main manufacturing center of the plant.

All of the raw materials are carried into the leaves and there worked over and converted into the refined products, which are carried to all parts of the plant to nourish the protoplasm. By the time a leaf unrolls from the spindle all of its

cells have been converted into permanent cells. Every one of them is assigned to some kind of work and none is allowed to remain embryonic; consequently, the leaf cannot grow any further; it cannot replenish worn-out tissues. It works hard if it can get the materials to work on, and in a comparatively short time becomes exhausted and dies, the work being carried on by the younger leaves, which are constantly being constructed and put into commission by the plant.

We are already familiar with the chief chemical task which is imposed upon the tissues of the leaf; this task being the manufacture of starch and its conversion into sugar. For this work it sets aside special tissues, the cells of which construct and operate chloroplasts and diastase.

In addition to its chemical work, the protoplasm of the cane leaf has certain important mechanical and physical problems to solve. The leaf is formed in a tightly-rolled tube, and it must be so constructed that it can unroll itself from the spindle when its turn comes. Then, as a mature leaf, it must support its entire blade, swinging free in the air while it is attached at the end only. To do this it must have strong tissues properly arranged to give the necessary support. Finally, the leaf must serve as a boiling-house or evaporator.

We have already noted that the cane plant secures a large number of elements from the soil, these being taken up in solution in water. Now, the soil-solution is always very weak, and in order to get the required amount of each element, the plant must concentrate this solution by evaporating off the excess water, just as we concentrate cane juice to syrup by evaporation. To facilitate this evaporation of water, the leaf is so constructed as to permit of a rather free circulation of air through its tissues. A mechanism is provided, however, whereby the protoplasm may control the ventilation so as to regulate evaporation. If the supply of water coming up to the leaf is meager, evaporation is reduced to a minimum; but if the supply is bountiful, the evaporator is worked at full capacity

Circulation of air through the tissues of the leaf also makes readily available two gases very essential to metabolism in the protoplasm of the plant. These gases are carbon dioxide and oxygen, both always present in the air. The carbon dioxide is absorbed and employed in the building of starch by the cells containing chloroplasts. The oxygen is used to oxidize or burn up compounds in order to release the chemical energy locked up in them.

Now, by referring to Fig. 16 we can get a pretty good idea of the complexity of the mechanism which the protoplasm, assigned to a leaf, builds in order to do the work required of a leaf.

The tegumentary tissue consists of a single layer of cells, the epidermis, extending over both surfaces of the leaf. The outer walls of the epidermal cells are very much thickened, and besides, are impregnated with cutin to render them impervious to water. Very little evaporation takes place through these walls. At intervals in the epidermis on the upper surface of the leaf there occur very large cells, as pointed out at 1, 3, 17 and 18 in the figure. These are known as motor cells, and in co-operation with certain large cells in the ground tissue, as 4 and 5, they cause the leaf to unroll and roll up by swelling or collapsing. When the leaf unrolls, these cells swell by simply filling up with water. As long as the leaf

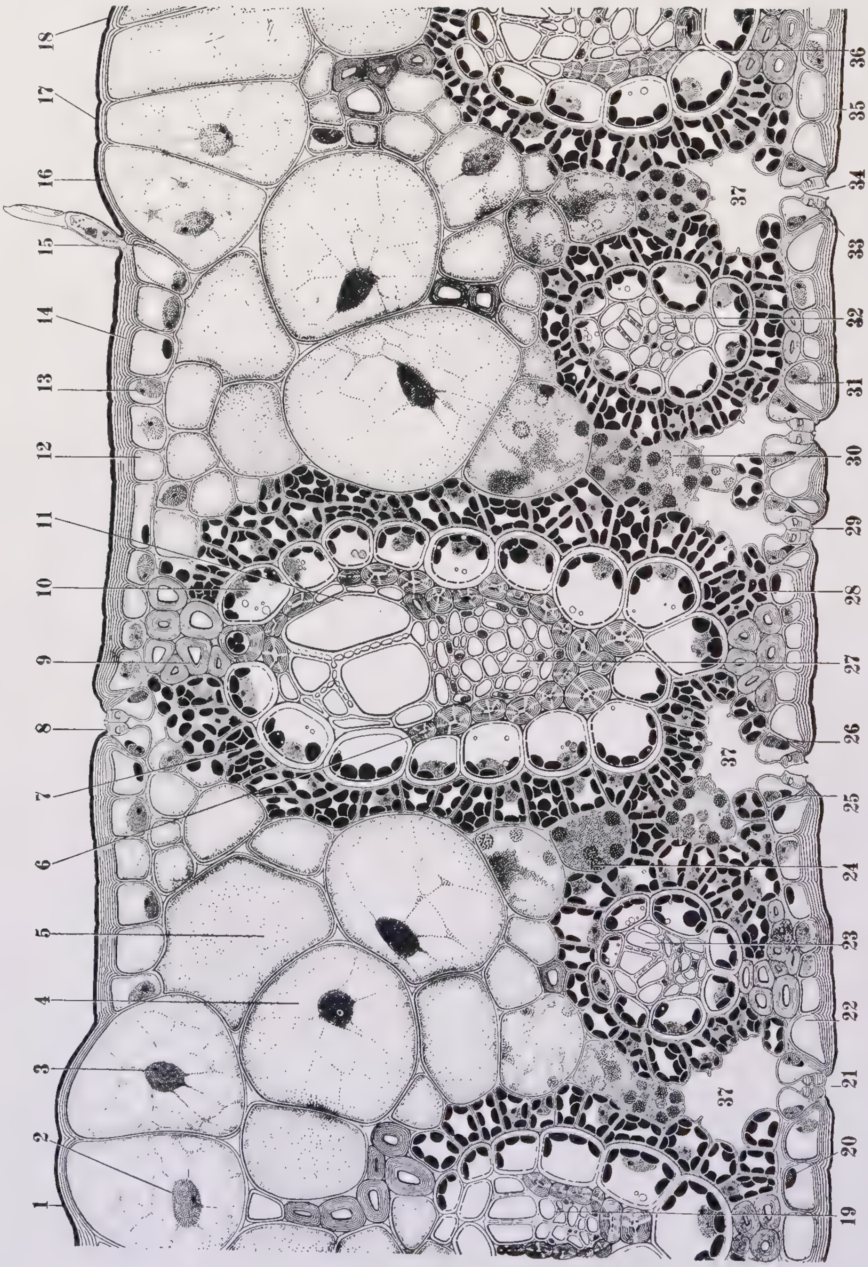


FIG. 16. Cross-section of a part of a cane leaf. For explanation see text.

is supplied with ample water they remain full and the leaf remains flat. If the water supply is deficient they lose water and collapse, causing the leaf to roll up again. A young leaf severed from a cane plant on a warm day quickly loses sufficient water by evaporation to cause it to roll up.

Ventilators or air pores occur in the epidermis on both sides of the leaf, but are much more numerous in that of the lower side (21, 29, etc.). These air pores, or stomata as they are called, are mere slits between two sausage-shaped cells known as the guard-cells. Each guard cell has a lip which may fit tightly against that of its companion, completely closing the air pore. If the guard cells are full of water they hold the lips apart and thus permit air to pass in and out of the leaf tissues, causing rapid evaporation of water. If the guard cells lose their water more rapidly than it is supplied to them, they begin to collapse and their lips approach each other, reducing the size of the opening and thus cutting down circulation and likewise evaporation. If the supply of water coming to the leaf is seriously curtailed, the guard cells collapse to a point where the stomata are completely closed. The opening and closing of the stomata is regulated automatically by the water supply; while there is an abundance of water they remain wide open, but they are very sensitive, and promptly reduce circulation if there is any curtailment of the water supply.

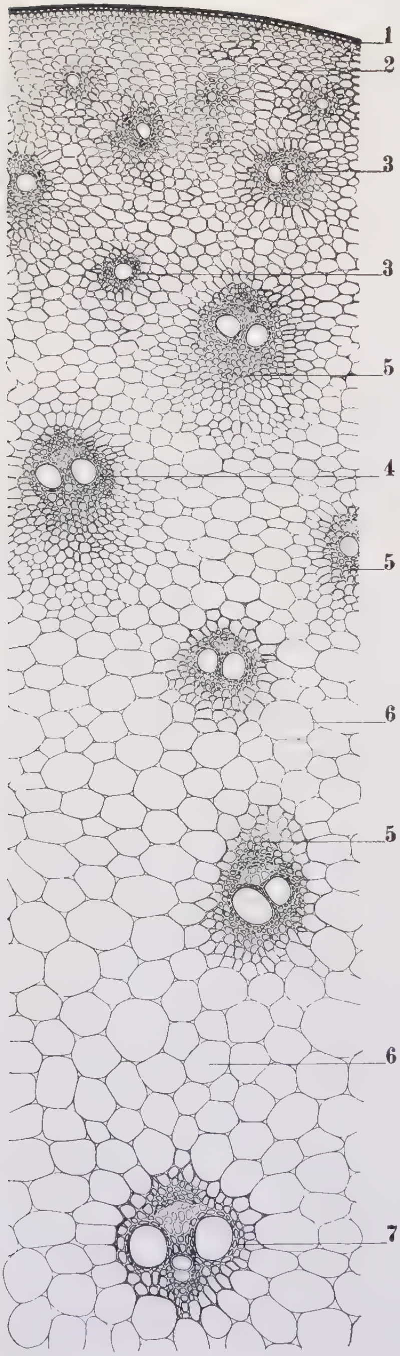
The stomata open into large air-chambers which communicate with intercellular spaces extending all through the ground tissue, providing channels along which the air may pass to practically every cell in the leaf.

Fibro-vascular bundles are very numerous in the leaf. They are of several different sizes, those which can be seen as veins on the surface of the leaf being even larger than the one shown in the center of Fig. 16. Their elements are the same as those already described for a bundle in the stem. Their arrangement is more compact, however, and the sclerenchyma is usually composed of thicker-walled cells. Each fibro-vascular bundle is surrounded by a layer of special cells of the ground tissue, known as the bundle-sheath (10). The cells in the bundle-sheath always contain a few chloroplastids. The principal chlorophyllous tissue is located directly outside of the bundle-sheath and consists of one or two layers of rather small cells. These cells are densely packed with chloroplastids, which are shown black in the figure. Chloroplastids also occur in the cells directly surrounding the air chambers.

The ground tissue supplies considerable sclerenchyma (thick-walled cells) to give strength to the leaf. This occurs mostly in the form of fibers just beneath the epidermis and opposite a vascular bundle, but isolated strands appear all through the ground tissue.

The chlorophyllous and motor cells of the ground tissue are thin-walled, and their walls are always saturated with moisture, so, as the air passes over their surfaces, carbon dioxide goes into solution in the water and is thus absorbed into the cells, while water is at the same time taken up and carried off by the moving currents of air.

In comparison to tissues of the leaf, those of the stem are relatively simple; in fact, we obtained a very good idea of these by examining sections of the stem



with the naked eye. Fig. 17 shows the structure of the stem as seen under moderate magnification. We are already familiar with the position and structure of the fibro-vascular bundles of the stem. The tegumentary tissue consists of a single layer of cells, the epidermis, with their outer walls cuticularized like those of the epidermal cells of the leaf. The cells of the ground tissue directly beneath the epidermis are very thick-walled also, and, with the epidermis, constitute what we commonly speak of as the rind. The rind is not a true tissue, and is not sharply marked off from the rest of the ground tissue. The cell walls of the ground tissue cells become gradually thinner as we progress inward from the epidermis, until they reach a thinness which is characteristic of the ground tissue throughout the greater part of its extent.

The chief functions of the tissues of the stem are to give support to the plant, to conduct water and to store up sugar. The sugar manufactured in the leaves is very promptly moved back into the stem and that which is not required for immediate consumption in the building of new protoplasm, and new tissue, is stored in the ground tissue of the stem. While sugar may be moved to some extent through the sieve-tissue, it is mostly handed on through the cell walls from cell to cell in the ground tissue.

FIG. 17. Section through the outer part of a cane stem. 1—epidermis; 2—thick-walled ground tissue cells forming the rind; 3, 4 and 7—vascular bundles of different sizes; 5—thick-walled supporting fibers; 6—thin-walled cells of the ground tissue.

The Kentucky Sanitary Privy.*

[*The privy vault in common use throughout Hawaii as a means of disposing of human wastes constitutes the greatest nuisance we have to deal with in providing better sanitation. Attempts have been made to make the ordinary privy fly-proof, none of which has worked out in practice. Disinfection at regular intervals helps out, but does not accomplish results we hope for. As a disease-breeder and means of providing for the distribution of disease-breeding germs, the privy vault has no equal.*

In order to make our plantation villages safe from the health point of view, ways and means of disposing of human excretions have had our attention and have been the cause of numerous experiments.

We are pleased to recommend for your consideration the Kentucky Sanitary Privy as described in a Bulletin issued by the State Board of Health of Kentucky in January, 1920.—*Industrial Service Bureau, H. S. P. A.*]

After years of study and painstaking experimental work, with helpful suggestions from many co-workers in this field, the State Board of Health offers this septic tank privy as the first forward step looking to the practical, effective, and economical disposal of wastes from the human body, in unsewered towns and country districts. In the various types of the tank described and illustrated in this Bulletin it will be seen that by increasing the length of the tank, and of each chamber thereof, indefinitely, and even the width and depth, where great capacity is required, it easily can be adapted to the needs of any home, school, hotel, health resort, court house, railway station, mining camp or similar place not on a line of public sewers.

In addition to the reliance which confiidently may be placed upon bacterial action for the destruction of disease germ life and the liquefying of all solid discharges, if properly constructed and cared for, and if no disinfectants are ever put in, the tank will be odorless, self-cleaning, fly-proof and will last forever. The invention is not patented; thousands of the tanks are in successful operation in this and other states and countries; in response to requests for plans and information about it, 250,000 bulletins have been sent over the country from Canada to Mexico and overseas countries.

The importance of actively and systematically extending this vitally essential feature of reform can hardly be overestimated. This movement may be forwarded by educational campaigns, direct legislation, as adopted in North Carolina, or other means, until every rural home in Kentucky enjoys its health and live-saving benefactions.

The average duration of human life in India, a retarded race in a country favored by nature, is 25 years, while in Sweden, less blessed naturally, but well

* Bulletin of the State Board of Health of Kentucky, January, 1920.

advanced in the observance of the laws of healthy living, the average of life is 54 years. Soper tells us within the present month that of the 1,600,000,000 people now in the world, only one per cent exist under proper living conditions. and that these fortunate few are constantly endangered by the large majority of their neighbors who do not so live. The truth of these estimates is borne out in Kentucky by the study of the sick and death rates, now collected and recorded under a rigid law, which shows that 60 per cent of the sickness and 47 per cent of the deaths occurring every year are from diseases which are distinctly and practicably preventable at far less cost than is required to care for the sick and bury the prematurely dead from them; and even more forcibly by the official records of the recent world war for the United States, which show that 34 per cent of those volunteering or chosen by selective draft were found upon exam-

Fig. 1. Organisms causing some of the more freqnent diseases of the lungs and air passages. All discharges containing them should be immediately and systematically burned or put in the tank.

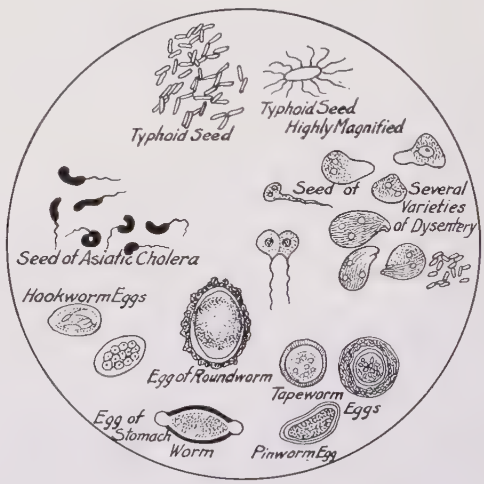


Fig. 2. Organisms causing some of the more common bowel diseases. These would be destroyed and all such diseases exterminated if everybody used a Kentucky Sanitary Privy.

ination to be as unfit for army service, as at least half of them were for the equally important duties of civil life, including, so far as the State and future generations are concerned, the paramount function of parenthood. It is hardly necessary to ask how far these physical defects and the high morbidity and mortality in Kentucky may be due to the fact that, even including sewered cities, over half the homes in this State are without a pretense of privies of any kind.

Germs peculiar to each of the communicable diseases, get into the body directly through its only portals, the mouth or nose, or are deposited in such hotbeds for their rapid and endless reproduction as are furnished by pollutions to be found around almost all homes not connected with modern sewers. The danger to all except immune persons becomes real and immediate, as shown by the 60 per cent of sickness and 47 per cent of deaths from these diseases occur-over half the homes in this State are without a pretense of privies of any kind.

In order to emphasize the importance of all this, it should be known that, except malaria and yellow fever, carried to man only by the bites of two of the

twenty-eight known varieties of mosquitoes; bubonic plague, by the bite of the rat-flea; hydrophobia, by the bites of dogs, cats, and other animals, and the venereal diseases, usually carried by immediate contact of the infected with non-infected persons, each of the communicable diseases is spread by its own peculiar germ or seed, the class causing the highest sick and death rate being excreted by those sick of them, or by carriers, through the mouth or nose, and all the balance through the bowels, except those of typhoid fever, which are also excreted

Fig. 3. Hookworm eggs (a to g) in various stages of development, found in abundance in discharges from bowels of hookworm patients, and young hookworms (i to k) ready to bore through the skin of any one who comes in contact with them. All highly magnified, since they are too small to be seen with the unaided eye. The privy destroys these, either in the egg or young hookworm stage.

through the kidneys. It is important, too, to bear in mind that the germs of each of these diseases, after its kind, although microscopic in size and with generations counted by hours and days rather than by months and years, as in the large animal and vegetable kingdoms, are as unlike in form, growth, and life history as the seed of corn is to wheat, or that of grass to clover. These have been so closely studied that trained health officials know the characteristics and

methods of spread and prevention of each of them as well as scientific farmers and orchardists do those of weeds, scale, and other pests to crops and fruit trees.

They know, for instance, that the germs of human tuberculosis, pneumonia, and all other infectious diseases, are excreted from the mouth and nose of the diseased person, and are spread by being carried to the mouth and nose of the well person. They know equally well that these diseases would be reduced to a minimum and finally exterminated if proper sanitary measures were employed, such as isolation of patients having an infectious disease, proper living conditions, etc. They know in the same way that the germs of typhoid fever and other intestinal diseases are excreted only from the bowels of the sick, or carriers of these diseases, and cause infection only by getting into the mouth or intestines of susceptible well people. If all such discharges could be immediately emptied into one of the septic tanks, these diseases would soon have only an historic interest to our people.

Essentials.

The essential principles of the privy are the tank and tile drain system, the inoculation by means of the well rotted horse manure, the carefully screened, clean, comfortable house.

The Location of the Privy.

This privy should be located as close to the house as is convenient, say not more than 10 or 15 feet from the back door, but it should be as far removed from a well or cistern as possible, to guard against accidental leaks in either structure. The privy should be placed on high ground and the drainage from it should be away from both the residence and the water supply.

Digging the Hole.

Having selected the location, the hole should be dug. For a privy of this size it should be 5 feet long, 4 feet wide, and 3 feet deep. It is best to mark out the size of the hole with stakes and a string and then dig the hole inside the string, but slightly smaller on all sides until it is nearly the required depth. Then the hole can be brought to exact size by carefully trimming the walls and bottom, making the sides smooth and exactly perpendicular, the corners square, and the bottom level. It is worth a little effort to make a neat job of the digging, since smooth walls and close measurements save cement and make the form easier to handle. If the pit is dug in sloping ground it should be dug three feet deep at the highest point and *no deeper. This is important.*

Constructing the Form.

At first sight the difficult part of the construction of a sanitary privy seems to be in making the form. In reality this is a very simple procedure. A study of Fig. 4 will show that there are only seven different sizes of parts, and if these are cut accurately to the sizes shown, there need be no trouble in putting them together. Begin by making the two sides, using A, B, C, and D, being sure that the battens are nailed on the inner faces of the sides. Then nail pieces E to the two sides so as to form the ends and baffles, putting the hole for the outlet tile

elbow in the end next to the "standing" baffle. The center of this hole must be 8 inches from the top of the form. This will bring the bottom of the outlet 2 inches below the top of the baffle.

Now nail on the four strips G, and, lastly, the two strips F. These parts, G and F, hold the top of the form in line and also make the shoulders in the concrete shown in Fig. 5, on which rest the seat riser and the boards for supporting the top.

Use six-penny nails for putting the form together, and do not clinch the ends if they should happen to come through. When done in this way there will be no difficulty in taking the form apart in order to remove it from the tank. By simply prizing off the battens "A," using ordinary care, the form may be removed

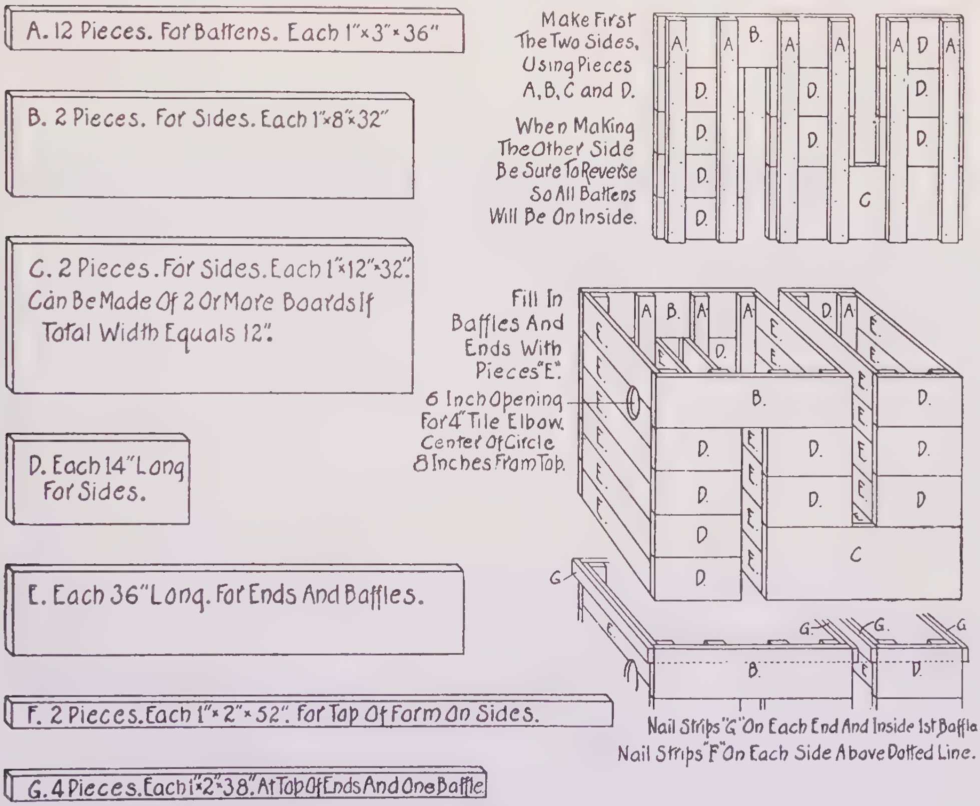


Fig. 4. Lumber for the forms for a small-sized tank. With care in fitting the parts together, as described in the context, and removing them after the concrete has well "set," the same form can be used over and over again for an entire community.

without damage and it may be used over and over again to construct other privies of this size.

The Mixing of the Concrete.

Concrete is a mixture of (a) Portland cement, (b) sand, (c) rock or gravel, and (d) water, which hardens upon standing. It varies in strength according to the proportions of the ingredients. In building a Kentucky sanitary privy

the same strength of concrete is used throughout. This is known as a 1-2-4 mixture and is composed of one sack of fresh Portland cement, two cubic feet of clean sand, and four cubic feet of broken rock or gravel. Broken limestone, in pieces never larger and preferably smaller than one inch in diameter, is best. Sand and gravel should be free from clay and other dirt or trash, such as leaves or sticks. The proportions given above should not be varied or changed. A richer mixture is more expensive and a weaker one will not be durable, or may cause the tank to leak. Before making the concrete it is best first to make a mixing board and a measuring box.

The mixing board should be about six feet square and should be tight enough to keep the liquid cement from running through, although small cracks can be stopped with sand. The measuring box should be made of four pieces of wood, besides the handles. On the inside it should be exactly two feet long, one foot wide, and one foot deep. Thus it holds exactly 2 cubic feet. This box has no bottom.

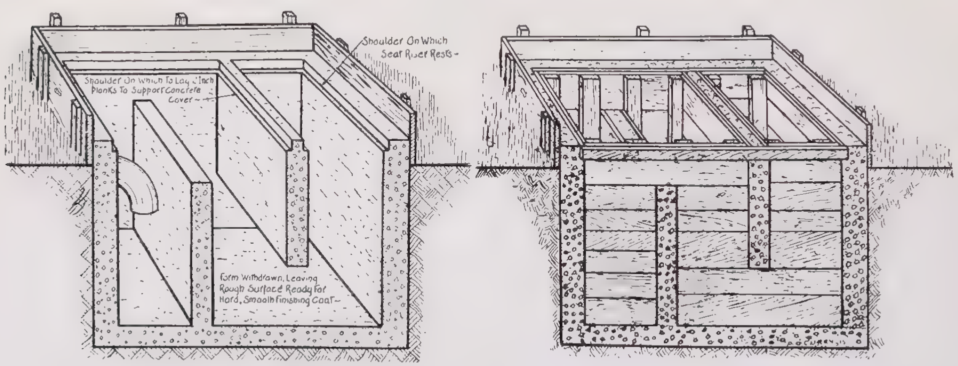


Fig. 5. Concrete poured and allowed to set before removing form.

To mix a batch of cement, set the measuring box in the center of the board and fill it level full of sand. Lift the box by the handles. The sand, 2 cubic feet, remains on the board. Set the box down again and fill twice with the clean gravel or rock, 4 cubic feet. Sprinkle over the rock and sand the contents of one sack of cement. This does not have to be measured, since a sack holds just one cubic foot of cement. Now thoroughly mix the *dry* cement and sand and rock by turning over and over on the mixing board with a shovel. After the cement and sand and rock are well mixed the water should be added, and again the whole mass should be mixed by repeatedly turning over and over with a shovel. An inexperienced person is very apt to use entirely too little water. A properly wetted batch should be so nearly a liquid mass that it will flow into place without much tamping. It should be about the consistency of rich cream or buttermilk and should easily find its level when slightly tamped or joggled with a thin plank or spade. Water is always cheap and easy to obtain and cement made without plenty of it will be hard to work and is apt to leave large crevices between the pieces of stone and cause a leak.

Do not make up a batch requiring more than one sack of cement at a time. Thus each successive batch will be fresh when placed in the form and will unite

perfectly with the preceding one and when set will be strong and durable. Be sure that the cement you buy is fresh. It should be as finely ground and as smooth as flour and entirely free from lumps and gritty masses.

Pouring in the Concrete for the Walls.

If the form and pit have been made according to the directions given above and the floor of the pit is level and smooth, it will be found when the form is in place, there will be a space of about five inches all around between the outside of the form and the walls of the pit. The top of the form will extend up above the ground about 8 inches. Use a spirit level to see that one side or end of the form is not higher than the other. Should the bottom be soft earth the form can often be made level by tapping on the high side, forcing it slightly down into the ground.

The 4-inch glazed tile elbow should now be placed in the opening made in the end of the form for that purpose, as shown in Fig. 5. Place the bell end of the tile snugly against the earthen wall and let the curved end project downward into the tank as shown in the drawings. It will be well to stop up the bell end of the elbow with a large wad of paper to prevent cement from flowing into it, but be sure to remove this wad before laying the balance of the drain.

The earth wall makes the outside form until the surface of the ground is reached, but around the outside of the hole above the ground a form should be built of four planks as shown in Fig. 5.

Now begin to pour concrete in the space for the walls, allowing it to come up evenly all around the form. As the concrete is poured it should be tamped or joggled slightly to cause it to flow into all the open spaces. By working a very thin plank or a spade up and down between the face of the concrete and the form, the larger pieces of rock will be forced back and only smooth concrete will remain in contact with the wood, and it will be found when the form is removed that this will give a smooth face to the inside of the concrete which will require very little work to finish smoothly with a trowel or brush.

Having poured the walls, the work must now be allowed to stand for twenty-four or forty-eight hours to "set," so that it will be hard and stand up when the form is removed. In the meantime the tank should be covered over to prevent too rapid drying of the exposed parts and to keep out rain and dirt.

While waiting for the tank to set you may, in order to save time, proceed to complete the tile drain.

After the concrete walls are safely set, so as to run no risk of breaking down, the inside form may be removed.

This is best done by simply prizing off battens "A." If the form has been put together with small nails this can be done with but little harm to the lumber and the form may be used over and over again to build other privies.

The form should be taken out *before the concrete is entirely dry* and then the entire inside of the tank, including the floor, must receive a smooth finishing coat made of equal parts of cement and sand, with plenty of water, and carefully applied with a brush or trowel. This finishing coat will not adhere to dry concrete, but when applied while it is moist it will adhere perfectly and render the tank completely waterproof.

Pouring the Top.

The next step is to put the "seat riser" in place. This is made of good dressed lumber, exactly to fit on the shoulder provided for that purpose over the first compartment, and should be about 21 inches high, so that, when the top is poured on, this seat riser will still project up 14 inches, which is about the right height for an adult's seat.

Over the balance of the tank place a covering of heavy planks one and one-half or two inches thick, in the shoulders left in the top of the walls for that purpose. This furnishes a support for the concrete cover while it is setting, and is not to be removed.

Now pour a layer of concrete about 2 inches thick over the entire top and around the seat riser. Then put in the reinforcing, which may consist of a piece of woven wire fencing, or iron rods, pieces of gas pipe or old buggy tires, and, on top of this, complete the pouring of the top until it has attained a thickness of five inches. While the concrete is still very soft place the four iron bolts head down in the cement about three inches from the edge and extending up two and one-half or three inches out of the concrete. The concrete should be tamped snugly up against the bolts and a large washer next to the head will anchor them still more strongly. These bolts serve to fasten the sills of the house firmly to the foundation, so that it will not blow off. The exposed surface of the top, which is to be the floor of the privy, should be finished with a rich mixture of concrete, half cement and half sand, and made perfectly smooth with a wooden float in order that it may be kept scrupulously clean.

Until the top of the tank has thoroughly set it should be well protected against injury from rain drops, too rapid drying, or other accidents. This is best done by covering it with a layer of wet tow sacks over which a layer of planks is placed. This will also prevent the concrete from cracking while seasoning.

The House.

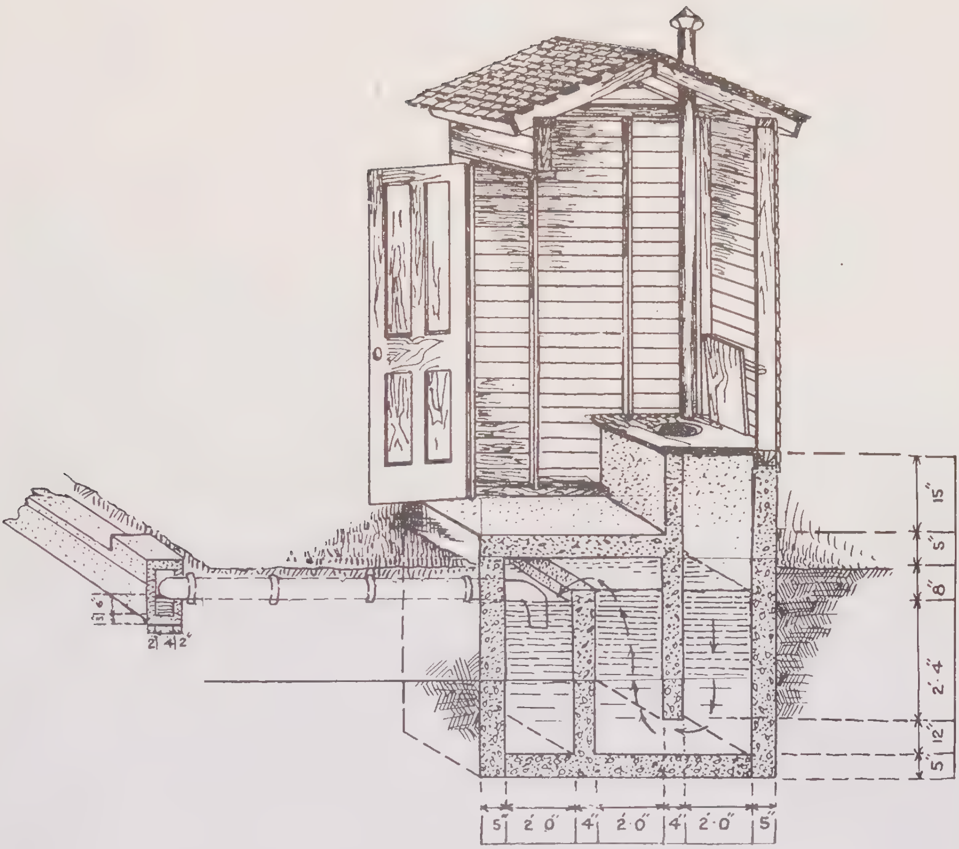
The house (Fig. 6) is a necesary part of any privy and it should be well constructed, pleasing in design, and, if possible, harmonious with its surroundings. It should have a good roof, and will be more comfortable if it is lighted and ventilated by a screened window placed high above the floor.

The Seat.

It is essential that the seat be constructed according to the design here given. As has already been shown, it must extend down into the concrete, forming a tight joint with it, and it must be provided with a well-fitted hinged cover to exclude flies and other disease-distributing insects. A block of wood nailed to the wall behind the seat will prevent it from remaining open when not in use.

Operating the Privy.

See that the tank is full of water until it begins to run out into the drain tile and make sure that the manure has been put in. Provide a good quality of tissue



Vertical Section of Tank and House.

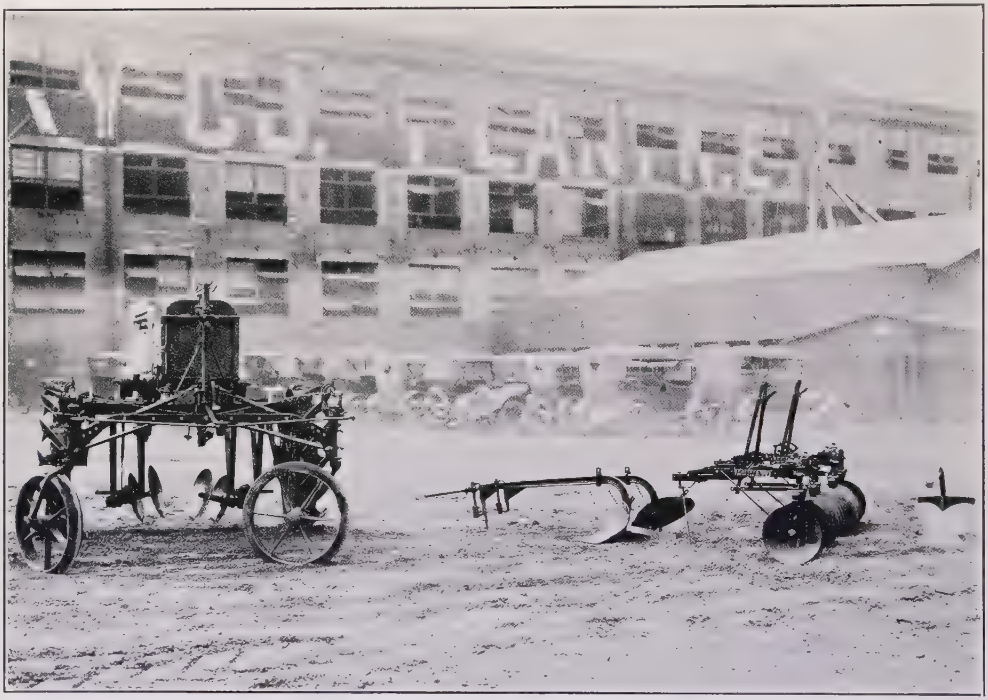
Fig. 6. A 600-gallon tank for a large family and home. It may be used for an outside privy, to receive the waste from an inside toilet and bath room, or for both purposes. By increasing the length of the tank and of each of the three chambers, indefinitely, and even the width and depth where great capacity is required, it easily can be adapted to the needs of schools, hotels, and similar public places. Properly managed, it is self-cleaning, odorless, fly-proof, and will last forever. The material for a tank of this size should not cost over $25.00.

toilet paper, since any other kind of paper will dissolve too slowly and will clog up the tank. When in constant use it will probably not be necessary to renew the supply of manure, but in case the privy is closed for a long period, as at a school during vacation, or when the home is unoccupied, it may be advisable to renew the manure when the tank is again put in operation.

A bucket of water must be poured in somewhat forcibly through each seat opening every day when the privy is being used. Not only does the privy require the addition of water, but no floating masses must be allowed to accumulate, so as to form a mat upon the surface of the water in the first compartment of the tank. Pouring water directly through each seat opening breaks up these masses

and causes them to dissolve easily. If a urinal is provided it also must be flushed in the same way each day. *If there is any odor from a properly constructed sanitary privy, it is because water is not being added every day in the proper manner and amount.*

New Implements for Sugar-Cane Culture.



This illustration shows a motor cultivator designed for the Argentine sugar districts. There are four different attachments, viz.: (1) a middle buster to be used in opening up the furrow in which to lay the seed cane; (2) a disk hiller which is to be used to cover the cane after it is planted; (3) off-barring plows for tearing down the ridges or throwing the dirt back; and (4) a reversible disk harrow attachment, with the idea of cultivating two middles at the same time.

Welded Boiler Explodes.*

At 11 a. m. on July 16, a small boiler of the firebox type exploded in a sawmill near McMinnville, Tenn., killing the fireman and a laborer, the former instantly, and badly scalding the owner and two others. The explosion was especially violent, completely demolishing the engine and mill equipment, and occurred without warning.

A few minutes before the explosion the owner noticed about one inch of water in the glass. The safety valve was popping off, and the gage showed 12 pounds. The owner instructed the fireman, a green hand, to turn off the injector, and when the glass stood half full, he turned off the injector himself. Two or three minutes afterward the explosion occurred.

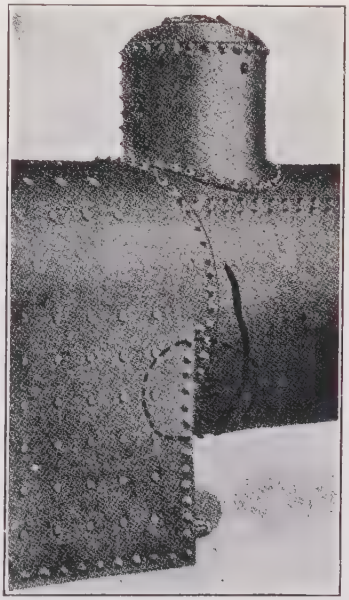


Fig. 1. Showing location of crack and corroded area.

Fig. 1 shows the type of boiler, the heavy irregular line indicating an old internal crack in the shell almost two feet long. Within the area inclosed by the dotted line the plates and staybolts showed evidence of having been badly corroded. Only four inches of this long crack was visible from the outside, and this portion was welded electrically about a year ago to prevent leakage. In welding, metal had simply been "spotted" over the crack, adding nothing to the strength of the sheet. The average thickness of the sheet over the entire length of the crack was something less than one-sixteenth inch. The condition of the sheet at this point may be seen in Fig. 2. The remainder of the metal in the boiler was in good condition, and the crown sheet showed no evidence of low water. The fusible plug was intact, although filled with shot lead.

The initial rupture apparently occurred at the point where the repair had been made by welding. The shell was torn entirely in two, and the two halves hurled one hundred feet away in opposite directions. The fracture followed the girth seam nearest the crack, but the violence of the explosion caused the shell to tear in several other places, and as part of the metal, including the steam dome, could not be found, it was impossible to trace exactly the entire course of the fracture.

This occurrence demonstrates the extreme hazard involved in operating even the smaller-sized boilers without experienced help and expert inspection,

* Power, August 10, 1920.

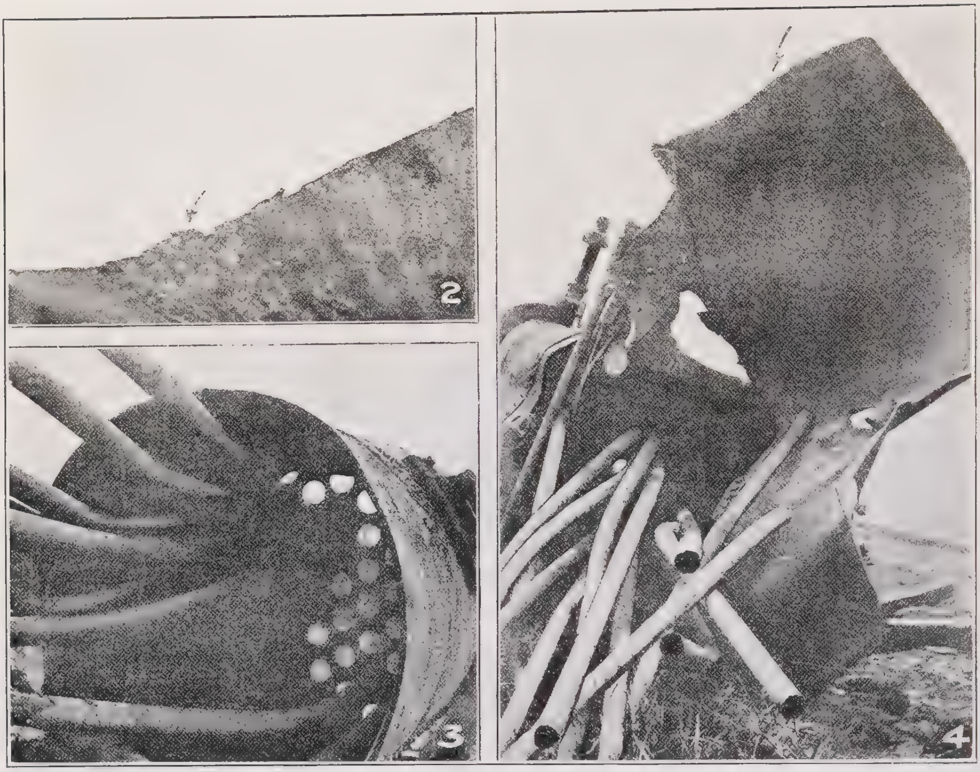


Fig. 2. The weld in which the metal was only spotted.
Fig. 3. Remains of front end. Fig. 4. Firebox end. Arrow indicates line of initial rupture.

and of attempting by the welding process a repair of the kind described. The owner of the plant was inclined to the belief that the initial failure could not have been at the crack, actually stating that the failure of the sheet at this point would have relieved the pressure and therefore have rendered an explosion impossible. Such statements point to the necessity of rigid state inspection laws, and of operation of boilers only by competent men. There are undoubtedly hundreds of boilers in daily use in as hazardous condition as this one was, the lives of the workmen and the safety of the equipment hanging by a very slender thread.

[W. E. S.]

The Prevention of Sugar Deterioration by the Use of Superheated Steam in Centrifugals.*

By Nicholas Kopeloff.‡

The deterioration of manufactured cane sugar has been the subject of considerable investigation to which reference has already been made.[1] Following a study of the most important single group of micro-organisms, the molds, responsible for sugar deterioration, the writer prepared a chart whereby it was possible to predict the keeping quality of a sugar.[2] It remained to devise some means of eliminating the causative organisms in order to prevent sugar deterioration. Shorey[3] and others have suggested the use of superheated steam in the centrifugals, but so far as we have been able to ascertain no controlled experiments have been conducted to test out the efficiency of such an agent. Unfortunately, it was not possible to arrange for an equipment in our sugar house and mill which would permit of such a study, and it was due to Assistant Director W. G. Taggart, who devised an apparatus to be used in the laboratory centrifugal, that the present experiment was made possible.

The centrifugal used was an 11-in., 1915 model, No. 2, made by the International Instrument Company of Cambridge, Mass. The jacket had a diameter of 11 in. and a depth of 3.5 in. A larger concave trough 15.25 in. in diameter and 6.5 in. deep caught the molasses. The device used for superheated steam was simple in construction, consisting of a half-inch intake pipe with two arms (3/8 in. diameter), one inside the basket, stopping 1.5 in. from the bottom, the other between the basket and the trough. These were made of copper, sealed off at the lower end, and had a slit in the side facing the surface of the sugar. The device was securely attached by means of screws to the outside trough. An autoclave was used as a source of steam, the outlet pipe being connected by a nipple and thick rubber tubing with a 10-in. superheater (or heating spiral such as used with an Abbé refractometer), which in turn was connected with rubber tubing to the device in the centrifugal through a hole in the cover, the latter being kept closed during the course of the experiment. Fig. 1 is a diagrammatic illustration of the apparatus used.

Confectioners' crystals, which are large in size, were sterilized and coated with a blackstrap molasses which was heavily inoculated with micro-organisms such as *Aspergillus* Sydowi Bainier, *Aspergillus niger, Penicillium expansum, B. vulgatus, B. megatherium, B. mesentericus,* and all the bacterial colonies developing from 150 plates poured from Cuban raw sugar. A massecuite of medium density was prepared and the centrifugal steamed out after receiving a swabbing with alcohol containing carbolic acid.

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* The Journal of Industrial and Engineering Chemistry, September, 1920.

‡ Louisiana Sugar Experiment Station, New Orleans, La.

1 Kopeloff and Kopeloff, Louisiana Experiment Station, Bulletin 166 (1919).

2 Louisiana Experiment Station, Bulletin 170 (1920).

3 J. Soc. Chem. Ind., 17 (1898), page 555.

The procedure was then as follows: The autoclave was run up to 22 lbs. pressure or a temperature of 263° F. The massecuite was heated to 104° F. (40° C.) for about 10 min., and poured into the centrifugal basket until it formed a layer three-fourths of an inch deep. The superheater was started with a Bunsen burner (asbestos being used to protect the rubber tubing) to get it well heated before the steam was added, then the centrifugal was put in operation (attaining a maximum of 3000 r. p. m.) and the steam turned on for 3 min.

Upon stopping the steam and centrifugal the temperature of the sugar was 155° F. (68° C.). Naturally, the sugar cooled very rapidly and doubtless the heat attained while the superheated steam was being applied was considerably in excess of this figure. The sugar was washed as white if not whiter than with a jet of water such as is ordinarily used. Samples of the sugar and the molasses coming from it were taken in sterile containers for bacteriological analysis.

The same procedure was repeated with a 1.5 in. layer of massecuite previously heated to 136° F. (58° C. for about 5 min. and at about 122° F. (50° C.)

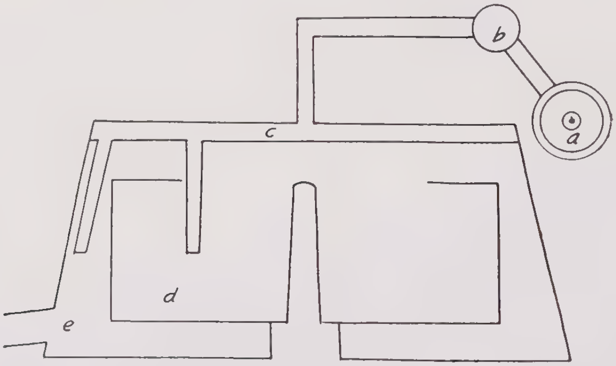

Fig. 1. Diagram of device for using superheated steam in laboratory centrifugal. a—autoclave; b—superheater; c—intake pipe with arms for delivering steam on inside and outside of basket; d—basket; e—jacket.

for 10 min. more. In this case the steam treatment was interrupted owing to a bend in the tubing which blew off one of the connections. At the end of the treatment the temperature of the sugar was 158° F. (70° C.).

The samples taken above were plated out in three dilutions on Kopeloff's agar,* incubated at 30° C., and read after 3 and 7 days. The data are presented in Table 1, in which are recorded the closely agreeing averages of quadruplicate determinations of each of the three dilutions.

TABLE 1.—EFFECT OF SUPERHEATED STEAM IN THE CENTRIFUGAL ON NUMBER OF MICRO-ORGANISMS IN SUGAR.

Treatment	Bacteria per Gram	Molds per Gram	Per Cent Reductions	
			Bacteria	Molds
Untreated, 40° C.	1,500,000	550	....	....
Steamed	8,000	10	99.47	98.28
Molasses	235,000	275	84.34	50.00
Untreated, 58° C.	200,000	110	....	....
Steamed†	14,000	10	93.00	90.91

* Loc. cit.
† Steam treatment interrupted.

It will readily be seen that in the first instance the untreated massecuite had 1,500,000 bacteria and 550 molds per gram, while the treatment with superheated steam resulted in reducing the content to 8000 bacteria and 10 molds per gram, a diminution of 99.47 per cent of the bacteria and 98.28 per cent of the molds, respectively.

This means an efficiency in the decimation of the micro-organisms which is remarkable and the significance of which will be discussed in detail presently.

The molasses from this sugar had 235,000 bacteria and 275 molds per gram, a reduction in 84.34 per cent of the bacteria and 50 per cent of the molds.

This is again proof of the sterilizing effect of superheated steam, since it may be inferred that the heat attained for the short time necessary to wash the molasses from the sugar was sufficient to kill more than three-fourths of the bacteria and one-half the molds. Furthermore, this is of practical value from the standpoint of the keeping quality of the molasses. We have previously referred to the unsanitary conditions under which most molasses is kept, frequently in tanks literally covered with a mat of mold mycelium. It is logical to suppose that where the original mass infection may be so materially reduced, the keeping quality of such a product may be greatly enhanced. Moreover, we have here an advantageous substitute for wash water which is frequently of questionable character and often responsible for a heavy inoculation with micro-organisms.

Moreover, these data indicate that by far the larger proportion of micro-organisms contained in the massecuite leave the centrifugal in the wash. Therefore, when it is the practice to separate the molasses and the wash, a less contaminated molasses is procured with undoubtedly improved keeping quality.

In this connection a digression may be permitted, which may be worthy of trial: namely, where molasses is not fermented and it is desired to keep it for some time, we would suggest the use of a thin layer of oil on the surface. This would prevent a mass infection at that vulnerable point and could be easily removed. The oil in this way need not affect either the quality, odor, or taste of the molasses. On the other hand, where mold growth already covers the surface it might be advisable to spray with toluene, which is cheap enough to be economical, germicidal enough to kill the molds, and volatile enough to be removed within a few days by exposure to the air. Since the pressure of time does not permit of the opportunity of developing these suggestions in the sugar mill, they are advanced for what they may be worth.

Returning to the latter half of Table 1, it will be seen that where the massecuite was heated to 122° F. (50° C.) the untreated sample contains only about one-eighth the number of bacteria and one-fifth the number of molds present in the massecuite heated to 104° F. (40° C.). This means that a partial sterilization has already been effected. The treatment with superheated steam was interrupted and the final results show that 93 per cent of the bacteria and 91 per cent of the molds were eliminated. It was to be expected that these figures would be somewhat below those obtained in the first instance, since the partial sterilization referred to probably eliminated the least resistant organisms and left a flora relatively more resistant than the one originally present. The interruption of the steam treatment must have been responsible for some loss in efficiency. Finally, the difference may be ascribed to the fact that the layer of sugar in this instance was twice as thick as that used in the first instance. It is to be expected

that four important factors would be operating in such an experiment, viz., temperature of steam, duration of application, thickness of layer of massecuite, and speed of centrifugal.

From the data set forth it is evident that the use of superheated steam under the conditions of the experiment was instrumental in almost entirely eliminating the micro-organisms present, the important consideration being that this was accomplished without increasing the moisture content of the sugar perceptibly, as in washing with water. As a matter of fact, under mill conditions it might be anticipated that even better results might be obtained where higher temperatures might be so readily available. The procedure has the merits of—

(1) Simplicity in construction and operation.

(2) Economy in equipment, installation, and operation.

(3) Efficiency under all conditions.

(4) Yielding a cleaner wash.

In working out a chart for predicting the keeping quality of sugar it was shown that two factors, moisture ratio and degree of infection,[1] operated simultaneously. It is obvious, therefore, that such a striking reduction in mass infection can be effected by the use of superheated steam in the centrifugals that the keeping quality may be greatly enhanced even where the moisture is somewhat more than it should be. For example, a sugar having a moisture ratio of 0.08 will deteriorate when 10,000 to 100,000 mold spores per gram are present. A reduction of 98 per cent, however, bringing the content down to about 1000 spores per gram, would make this sugar safe even though the moisture ratio increased to as much as 0.14 to 0.16.

Thus it may be said that in the investigations on sugar deterioration carried forward in this laboratory, the study of the micro-organisms and their activities, which made possible the prediction of the keeping quality of sugars, has found its logical completion in the development of an adequate means for eliminating the micro-organisms and consequently preventing sugar deterioration. However, it must be emphasized again that the sugar must be properly handled under sanitary conditions with a minimum possibility of absorbing moisture in order to ensure its safe keeping, since, under optimum conditions, the micro-organisms soon propagate rapidly enough to become detrimental.

Summary.

1. A simple, economical, and efficient method has been developed for employing superheated steam in laboratory centrifugals.

2. By means of this treatment the bacterial content of sugar has been reduced 93 to 99.5 per cent, and the number of mold spores has been reduced 92 to 98 per cent. The micro-organisms in molasses are reduced similarly to a lesser extent.

3. This elimination of micro-organisms improves the keeping quality of the sugar as well as the molasses.

4. With superheated steam treatment, the practice of separating molasses and wash results in a considerable reduction of micro-organisms in molasses, with consequent improvement in its keeping quality.

[W. R. M.]

[1] Loc. cit.

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